





Digitized by the Internet Archive
in 2011 with funding from
University of Toronto

13-3/4
Tech
F

THE JOURNAL
OF THE

FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

EDITED BY

MR. LOUIS E. LEVY, Chairman; MR. EDWIN S. BALCH, MR. JOHN
BIRKINEINE, MR. JAMES CHRISTIE, MR. EDWARD

H. SANBORN, Committee on Publications; with the
Assistance of the Secretary of the Institute.

VOL. CLXX.—Nos. 1015-1020
(85th YEAR)

JULY-DECEMBER, 1910

PHILADELPHIA

Published by the Institute, at the Hall, 15 South Seventh Street.

1910

T
-
F8
V.170

621361
24 10 55

The JOURNAL OF THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

JULY, 1910

No. 1

MAGNETIC HYSTERESIS.

BY

MORTON G. LLOYD,

Associate Physicist, Bureau of Standards, Washington, D. C.

*(Presented at a Stated Meeting of the Electrical Section, held Thursday,
April 28, 1910.)*

[Essential to the correct design of electrical machinery is a complete knowledge of the physical magnetic and electrical properties of the elements which enter most largely into its composition, namely, steel or iron, copper, and insulating material. In the following paper the Author treats exhaustively of the latest methods of measuring magnetic quality in general and in particular the losses which occur in iron and iron alloys when placed in alternating and rotary magnetic fields. The results clearly show the great improvement made in recent years in the quality of the magnetic material used in such enormous quantities by the manufacturer of electrical apparatus of to-day. They also show along what lines research may be made with the probable result of still greater improvement.]

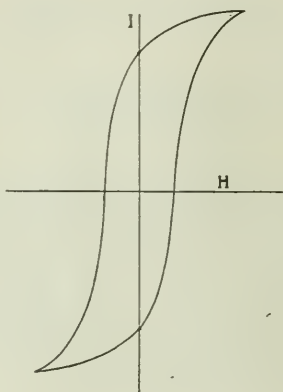
THE name 'hysteresis' is applied to the tendency of magnetic materials to persist in any magnetic state which already exists. It is due to this property that we have such a thing as a permanent magnet. If a specimen is exposed to a magnetizing field which gradually increases in value and then gradually decreases, the value of the resultant magnetization corresponding to a particular magnetizing field is different for increasing and for decreasing values. The magnetizing field may be reduced to zero, but some residual magnetization remains, and it requires a negative magnetizing field to reduce the magnetization to zero.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

In short, the magnetization appears to lag behind the changes in the magnetizing field, and it was for this reason that Prof. Ewing suggested the name 'hysteresis' for this phenomenon.

It can easily be proven that this magnetic lag is a necessary and sufficient condition for a resultant transformation of energy which accompanies any cyclic process of magnetization. If we plot a curve between the values of magnetizing field H and the corresponding intensity of magnetization I , as in Fig. 1, then the area enclosed by the curve representing a complete cycle of changes represents the energy expended on the material, as was shown by Warburg in 1881. The energy expended appears in the material in the form of heat, and this transformation of energy is of enormous importance industrially. Every electric

FIG. 1.



Hysteresis loop.

generator, motor and transformer, as well as many other pieces of apparatus employing iron or steel in which the magnetization is changing, is an example of this fact. In all such apparatus employing iron cores, very careful consideration must be given by the designer to the problem of keeping down this magnetic hysteresis to the lowest value consistent with the other considerations of design. Not only does the hysteresis cause a great waste of power, but on account of the development of heat it helps to put a limit to the capacity of the apparatus, for the rated capacity is usually based upon the permissible rise of temperature.

According to the reports of the U. S. Bureau of the Census,

there were manufactured in this country in 1905 66,698 transformers with a total capacity of 970,908 horsepower. I have estimated that the core losses in these transformers would not be less than 7800 kilowatts, and with a cost of power of one-half cent per kilowatt-hour they would consume in core loss in one year power to the value of \$340,000. Between 1900 and 1905 the yearly output of transformers more than doubled. If we assume that this rate of increase has been constant, we can compute the total number of transformers in use to-day and the power wasted in them annually through core loss. An estimation on this basis indicates that there is now expended in this country to supply core losses in transformers alone, power costing nearly \$4,000,000 annually.

As the output of motors annually is about two-thirds the output of transformers, measured in power rating, and as the output in generator capacity is about 50 per cent. greater than the output of transformers, it is evident that the total expenditure for core losses must reach an enormous sum, probably over \$10,000,000 annually.

All of this enormous waste is not due to hysteresis, since eddy currents in the core conspire with the hysteresis to make up the total. The eddy-current loss, however, is usually the smaller part of the total, so that the magnetic hysteresis must accept the responsibility for dissipating each year the major part of this vast expenditure of energy in the form of heat. If the heat could be stored up for the winter months and utilized in heating our buildings a prodigious saving might be accomplished and the depletion of our coal supply somewhat delayed.

Not only the industrial importance of hysteresis, but also the scientific interest which its discovery aroused, has led to a great many investigations into the causes of the phenomenon, the conditions which affect its value, and the best methods of measuring it.

The methods of measuring hysteresis are numerous, and I shall not take time to discuss all of them. I have already pointed out that the area of the hysteresis loop obtained by plotting a curve between H and I represents the energy expended per unit volume of material under the particular conditions of the experiment. The constant of proportionality depends of course upon the scale and units employed, and is easily determined. If the

flux density in the material, B , be used as a co-ordinate of the curves, instead of I , the area of the loop will still represent the energy expended, but the constant of proportionality will be altered. Consequently any method of measuring the corresponding values of either pair of quantities will suffice to plot a hysteresis loop and thus determine the energy expended in the cycle. One well-known method is by use of the magnetometer, whose deflections give a measure of I for any applied H . In this method the specimen is preferably in the form of an ellipsoid, or of a long thin wire.

Another method employs a ballistic galvanometer connected to a coil of wire surrounding the specimen, the throw of the galvanometer produced by any change in the magnetizing field being a measure of the corresponding change of magnetic flux in the specimen. It is desirable in this method to have a closed path of magnetic material, and the specimen is either chosen in the form of a ring, or else massive yokes are used to complete the magnetic circuit. Various forms of ingenious apparatus have been devised for mechanically drawing the hysteresis loop, and there are also a number of commercial permeameters in the field for facilitating these measurements, such as the apparatus of Koepsel, Esterline, Carpentier, or Bruger.

The determination of hysteretic loss of energy by drawing the loop is a tedious and inconvenient process, since the curve is usually determined point by point, and the area must then be measured by planimeter or other slow means. Consequently methods and apparatus have been devised for giving the desired results directly from the instrumental readings.

In the Ewing hysteresis tester, the specimen is rotated between the poles of a permanent magnet, which experiences a torque in the direction of rotation due to the hysteresis in the specimen. The magnet is displaced until the torque is balanced by gravity and the deflection read by means of a pointer moving over a graduated scale. The flux density is determined principally by the length of the specimen and is little influenced by the cross-section, within certain limits. If specimens are cut accurately to a prescribed length, comparative readings are thus obtained for one particular flux-density.

The Blondel-Carpentier instrument is similar in principle, but uses a ring specimen and a rotating U-magnet. The torque

exerted on the ring is opposed by a spring, and is indicated by a horizontal pointer.

In both of these instruments, if the rotation takes place at a low speed, as when turned by hand, the eddy currents have very little effect and the torque is approximately proportional to the hysteresis. The usual flux-density obtained in the Ewing apparatus is 4000 gaussess, and in the Blondel tester 10,000 gaussess.

Each apparatus is subject to the same limitations, such as giving results for only one flux-density, and requiring a standard sample of known constants for comparison.

The most direct means of measuring hysteresis in general, without bringing in eddy current effects, is supplied by the ballistic dynamometer. This instrument differs from the ordinary electro-dynamometer in having a moving coil with a long period of swing. In using it, the current which produces the magnetizing field is sent through the fixed coils, while the moving coil is connected to a winding which surrounds the magnetic flux. Upon reversal of the magnetizing current, the induced current in the circuit of the moving coil produces a temporary deflection or throw in the instrument which can be shown to be proportional to the hysteretic energy for the half-cycle.

Just as a galvanometer measures current in its ordinary use, but quantity of electricity when used ballistically, so the dynamometer measures energy by its ballistic throw, but power, or rate of energy, when used with currents giving steady deflections.

The ballistic dynamometer thus gives by a single observation the quantity desired. This simple and elegant method of measurement was first proposed by Searle,¹ and has lately been utilized by Rice and McCollum.²

The core losses encountered in electrical apparatus do not consist of hysteresis alone, but are augmented by the presence of eddy currents in the iron. The magnitude of the eddy currents is diminished by laminating the core, *i.e.*, by building it up of separate sheets, which are electrically insulated by a thin coating of japan, or sometimes left without other insulation than that afforded by the coating of oxide which usually forms the surface of the sheet. In the commercial testing of core material it is not merely the determination of hysteresis which is desired, but the

¹ G. F. C. Searle, Electrician, 1896, xxxvi, 800.

² M. E. Rice and Burton McCollum, Phys. Rev., 1909, xxviii, 132.

determination of the total power consumption due to both hysteresis and eddy currents under definite conditions of flux density and frequency of alternation. Testing methods have consequently been employed which subject the material to conditions very similar to those met with in service.

In general, alternating current is used to create a magnetizing field, and the power required to continually reverse the magnetization of the iron is measured by a wattmeter. The material is sometimes used in the form of rings, and to obviate the necessity of winding a magnetizing coil on each specimen, apparatus has been built by Möllinger³ and by Esterline⁴ in which the winding is divided, so that the specimen can be inserted and taken out. A ring form has the advantage that an unbroken magnetic circuit of the material is secured, and there is little opportunity for magnetic leakage, or variation of the flux between successive parts of the magnetic circuit. On the other hand, to secure uniformity of the flux across the section of the ring, it is necessary that the radial breadth of this section be small in comparison to the diameter of the ring. In the case of sheet material, this condition can only be fulfilled by making the rings of unwieldy size or else very narrow. The latter alternative is objectionable because the material near the cut edge is hardened by the cutting, and in a narrow strip the average value is too greatly influenced by this hardened portion.

In Fig. 2 is shown the effect of the uneven distribution of flux found in rings of small diameter. One curve is given for rings of square section, and one for circular section. Each curve gives, for different relative dimensions, the ratio of the hysteresis for a uniform distribution of flux to that actually found. In computing these values it is assumed that the permeability of the material is uniform, but this is not always true, since the permeability is itself dependent upon the flux-density, having its highest value for a medium flux-density, the particular value of which varies from one specimen to another. When using a flux-density lower than this particular value, the distribution of flux is more uneven than assumed in the curves, and the resulting errors will be greater, whereas for higher flux-densities the reverse is the case.

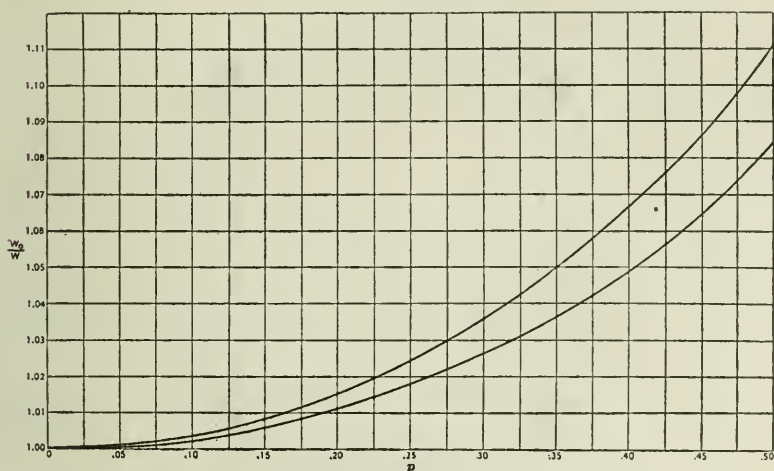
³ J. A. Möllinger, *Electrot. Zs.*, 1901, xxii, 379.

⁴ J. W. Esterline, *Prac. Am. Soc. Testing Materials*, 1903, iii, 288.

An apparatus was introduced by Richter⁵ for testing entire sheets of iron. It consists of a thin magnetizing coil in the shape of a barrel, with a slot left at one point for the introduction of the sheet. The sheets are shoved around until the two ends come in contact, forming a closed magnetic circuit. This method obviates the necessity of cutting up samples, wastes no material, and gives at once the average value of the whole sheet. It has the disadvantage of bending the sheet, which may alter the quantity sought.

The Epstein apparatus makes use of straight strips which are assembled in bundles and placed in four solenoids forming

FIG. 2



Curves showing ratio of hysteresis in uniform field to actual hysteresis for rings of rectangular (upper curve) and circular (lower curve) cross-sections; p is the ratio of radial width of section to diameter of ring.

the sides of a square. The magnetic circuit is interrupted at the corners by pieces of cardboard inserted between the ends of the bundles. This method has been adopted in Germany by the Association of Electrical Engineers, and their standard test is the determination of watts per kilogram at a flux-density of 10,000 gauss and a frequency of 50 cycles per second.

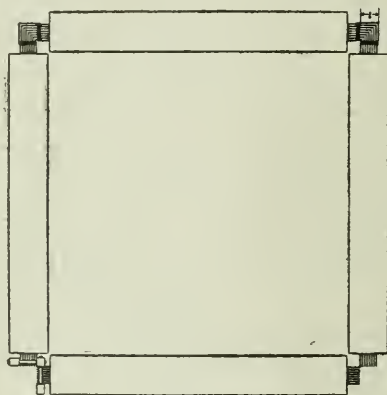
A modification of the Epstein apparatus has been developed at the Bureau of Standards by Mr. J. V. S. Fisher and the

⁵ R. Richter, *Electrot. Zs.*, 1903, p. 341.

speaker.⁶ The modification consists principally in mounting the bundles with their faces, instead of their edges, toward the centre of the square, and making good magnetic joints at the corners by the aid of special corner pieces. This arrangement enables wide strips to be used while keeping the radial breadth of the core small, so that the distribution of flux is very uniform; the avoidance of gaps in the magnetic circuit keeps the magnetizing current low and thus distortion of the wave-form can be avoided while using a much smaller quantity of iron. The reason for this will be made clear below.

The plan of this apparatus is shown in Fig. 3, and Fig. 4 gives a diagram of connections. Each solenoid consists of a mag-

FIG. 3.



Plan of apparatus.

netizing coil and a secondary winding, the windings of the four solenoids being connected respectively in series. The source of current is connected to the magnetizing coils through the wattmeter and ammeter. The secondary windings are connected to the potential circuit of the wattmeter through a non-inductive resistance R_1 . When used in this way the wattmeter deflections are a measure of the energy expended in the core and the secondary circuits, but do not involve the copper loss in the magnetizing coil. Another circuit connected to the secondary coils

⁶ A fuller description of this apparatus is given in Reprint No. 109 from the Bulletin of the Bureau of Standards.

contains a voltmeter and a non-inductive resistance, R_2 . A frequency meter is connected across the mains.

The purpose of the voltmeter is to determine the magnetic flux in the material tested. The voltage induced in the secondary

FIG. 4

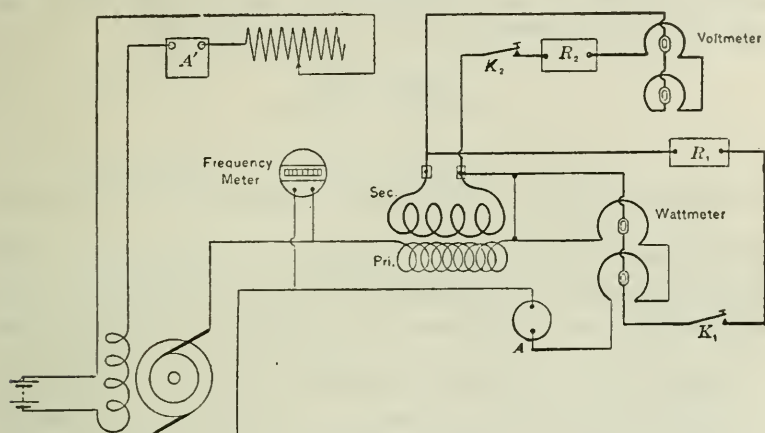


Diagram of connections.

winding by the varying flux is itself a variable quantity, its mean value in volts being given by the expression :

$$Em = 4 N n \phi \cdot 10^{-8}$$

where

n = frequency in cycles per second

N = number of turns

ϕ = flux in maxwells.

Most types of voltmeters measure, not the mean value of the voltage, but the effective, or r.m.s. value. The ratio of the effective to the mean value is called the form-factor. Consequently if

f = form factor of secondary voltage

A = area of cross-section of specimen

B = flux per unit area

E = effective voltage

we have

$$E = 4 f n N B A \cdot 10^{-8}$$

It is preferable to work with a wave of definite shape, so that f has a specified value. The sine wave is the most suitable and for this f has the value $\frac{\pi}{2\sqrt{2}} = 1.1107$.

In order to have a sine wave of secondary e.m.f. it is not sufficient merely to have a sine wave of applied e.m.f. from the generator. The instantaneous e.m.f. of the generator

$$e = N_1 \frac{d\varphi}{dt} + L \frac{di}{dt} + ri$$

The secondary e.m.f. is $N_2 \frac{d\varphi}{dt}$ and to be sinusoidal it is necessary that $N_1 \frac{d\varphi}{dt}$ also be sinusoidal. It is only when the last two terms are negligible that the generator e.m.f. and the secondary e.m.f. will have the same wave form. This condition is fulfilled either by using a large cross-section of material (thus making $\frac{d\varphi}{dt}$ large) or by keeping the last two terms low. The latter is attained by avoiding leakage flux, undue resistance in the magnetizing circuit and undue reluctance in the magnetic circuit, since the latter increases the magnetizing current i .

This condition also puts a limit to the values of B and n which may be used without wave-distortion, since too low values of either will reduce $\frac{d\varphi}{dt}$ too much, and values of B approaching magnetic saturation will increase i unduly.

Table I gives some of the results which have been obtained with this apparatus.

An investigation by Steinmetz in 1892 led to the establishment of an empirical relation connecting the hysteretic loss of energy with the maximum value of the flux-density reached during the cycle. That is, if the flux-density alternates between the values $+B$ and $-B$ the loss of energy per cycle and per unit volume is equal to ηB^κ where η is a constant depending upon the material, and to the exponent κ was assigned the value 1.6. Later investigations have shown that this relation is not rigorous, that the exponent κ is not constant, but departs widely from 1.6 at very high and very low flux-densities; and that the loss at high flux-densities is more correctly expressed in terms of $I^{1.6}$

MAGNETIC HYSTERESIS.

TABLE I.—ORDINARY STEEL.

Designation	Thickness cm.	Ergs per Gram per Cycle										Watts per Pound at 60 Cycles and 10000 gausscs			μ	γ
		10000 gausscs					5000 gausscs									
		60°	30°	Hysteresis	Eddy currents	60°	30°	Hysteresis	Eddy currents	Eddy currents for Ergs 29	Hysteresis	Total				
E	0.0476	971	853	735	236	304	275	246	58	0.36	2.00	2.36	1.58	2.02		
F	0.0280	706	716	606	100	247	233.5	220	27	0.44	1.81	2.25	1.60	1.88		
G	0.0304	773	668	563	210	247	220	193	54	0.47	1.53	2.00	1.54	1.90		
H	0.0307	558	485	412	146	177.5	158	138.5	39	0.54	1.12	1.66	1.58	1.90		
I	0.0318	543	442	341	202	166.5	139	111.5	55	0.70	0.93	1.63	1.62	1.88		
K	0.0282	518	456	394	124	162	146	130	32	0.54	1.07	1.61	1.61	1.90		
L	0.0340	505	473	381	184	175	150	125	50	0.535	1.035	1.57	1.61	1.88		
Br	0.0338	554	454	354	200	173	144.5	116	57	0.61	0.96	1.57	1.61	1.81		
M	0.0335	550	461	372	178	173	150	127	46	0.55	1.01	1.56	1.55	1.95		
N	0.0340	531	426	321	210	161	133	105	56	0.63	0.87	1.50	1.62	1.90		
P	0.0437	518	426	334	184	157	132	107	50	0.335	0.91	1.24	1.64	1.88		
SILICON STEEL.																
Q	0.0361	357	330	303	54	113	105.5	98	15	0.14	0.82	0.96	1.63			
R	0.0315	330	309	288	42	104	98.5	93	11	0.15	0.78	0.93	1.64			
S	0.0452	350	314	278	72	108	99	90	18	0.12	0.76	0.88	1.63			
T	0.0338	310	280	250	60	96	87	78	18	0.18	0.68	0.86	1.68			
U	0.0346	312	291	270	42	98	92	86	12	0.12	0.74	0.86	1.66			
V	0.0310	298	275	251	47	92	85.5	79	13	0.17	0.68	0.85	1.68			
W	0.0305	240	218	197	43	74.7	68.5	62.3	12.4	0.16	0.54	0.70	1.67			
X	0.0430	205	232	200	65	80.8	72.5	64.2	16.6	0.12	0.54	0.66	1.65			

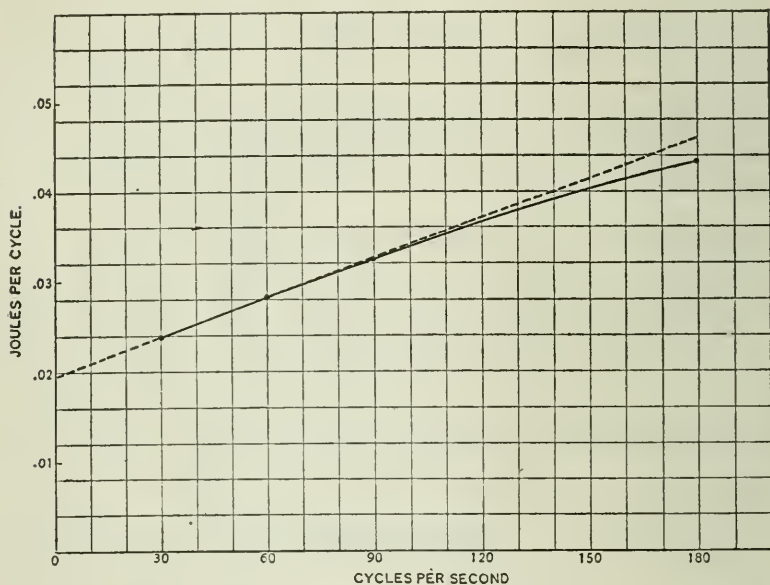
where I is the intensity of magnetization and is related to the flux-density by the equation

$$B = H + 4\pi I$$

For moderate flux-densities, and more especially in the region of industrial operation, the Steinmetz Law is a very close approximation to the truth and has been of great usefulness.

When alternating current is used for producing magnetiza-

FIG. 5.



Loss per cycle for different frequencies.

tion we must consider not only the hysteretic loss of energy but also that due to eddy currents. If a sine wave be used, the total power per unit volume is given by

$$W = \eta n B^{\kappa} + \zeta n^2 B^{\gamma}$$

where n is the frequency in cycles per second, and ζ a constant depending upon the electrical conductivity of the material and its dimensions. Since the hysteresis loss is proportional to the frequency and the eddy current loss to the square of the frequency, these two components of the total loss can be separately

determined by observations at two or more frequencies. Fig. 5 is a curve plotted between loss per cycle and frequency. For the lower frequencies this is sensibly straight, and by projecting back to the axis the hysteresis per cycle is given by the intercept on the axis. The exponent y has been shown on theoretical grounds to have the value 2 for an infinite thin sheet, and under practical conditions it approximates closely to this value for sheet iron or steel. The values of the exponents κ and y can be determined by measuring the losses at different flux-densities. The values of y given in Table I are computed from measurements made at 5000 and 10,000 gaussess, the separation of losses being

TABLE II.—VALUES OF HYSTERETIC CONSTANT.

Material	η	Authority
Hard tungsten steel.....	0.058	Steinmetz
Hard nickel.....	0.039	Steinmetz
Hard cast steel.....	0.025	Steinmetz
Magnetic iron ore.....	0.020	Steinmetz
Forged steel.....	0.020	Steinmetz
Two-mil steel wire.....	0.016	Lloyd
Cast iron.....	0.013	Steinmetz
Soft nickel.....	0.013	Steinmetz
Cast steel.....	0.012	Steinmetz
Cobalt.....	0.012	Steinmetz
Heusler alloy I.....	0.012	Gumlich
Electrolytic iron.....	0.009	Schild
Soft machine steel.....	0.009	Foster
Annealed cast steel.....	0.008	Foster
No. 36 iron wire.....	0.005	Lloyd
Ordinary sheet iron.....	0.004	Lloyd
Pure iron.....	0.003	Gumlich
Heusler alloy II.....	0.0024	Gumlich
Soft iron wire.....	0.002	Foster
Annealed iron sheet.....	0.002	Lloyd
Ingot iron.....	0.0016	Lloyd
Best annealed sheet.....	0.0010	Lloyd
Silicon steel sheet.....	0.0010	Lloyd
Silicon steel.....	0.0009	Gumlich
Best silicon steel.....	0.0006	Lloyd

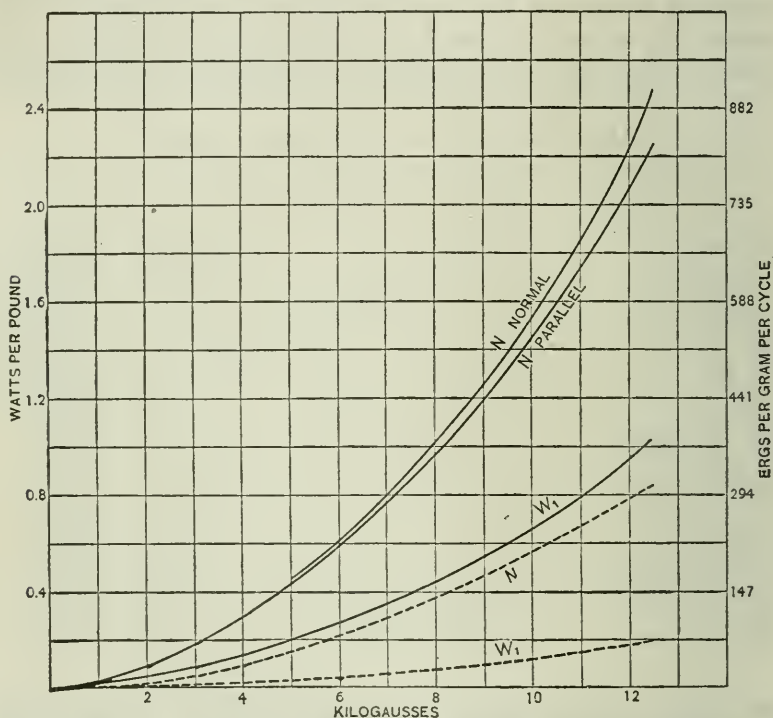
effected by means of runs at 30 and at 60 cycles. The values of η are computed for 10,000 gaussess. In Fig. 6, the solid curves show the relation between core loss and flux-density for two specimens. For specimen *N* a difference was found according as the sheet was magnetized parallel or normal to the direction of rolling. The dotted lines give eddy current loss at sixty cycles.

Table II gives values of η collected from various sources, for a wide variety of materials.

The importance of hysteresis to the manufacturer of elec-

trical apparatus has been already pointed out. Since an improvement in both efficiency and capacity results from diminishing the core loss, efforts are constantly being directed toward the improvement of the core material. The best material will not only have a low hysteretic constant, but must also have a low electric conductivity in order to suppress eddy currents. When the difference between hard steel and soft iron was first recorded,

FIG. 6.



Dependence of losses on flux density, showing the difference when sheet is magnetized parallel or normal to the direction of rolling. Full lines show total loss, dotted lines the eddy-current loss. Sixty cycles.

men jumped to the conclusion that the softer and purer the iron could be obtained, the better would be the results. The annealing of electric sheets was therefore universally practised and Norwegian and Swedish iron were universally demanded. The later preparation of electrolytic iron and of chemically pure iron has shown that increased purity does not improve the properties of the iron. On the other hand investigators have examined more

closely the effects of different impurities, and it has been found that certain impurities are beneficial. As early as 1896 a patent was taken out in this country by J. F. Kelly,* covering a core in which the percentage of silicon was unusually large. It had been found by Kelly that a slight increase in the amount of silicon, not exceeding 0.03 per cent., made the sheets more stable, so that the hysteresis did not increase after the apparatus was put in service, a phenomenon which was quite common in soft iron and the mild grades of steel previously used. A few years later, Hadfield, in England, experimented with a number of alloy-steels and it was found that either aluminum or silicon would greatly improve the magnetic quality when introduced in the proportion of 2 or 3 per cent. Silicon-steel has proved the most useful industrially and in 1903 Hadfield † was granted a patent covering the use of this ingredient to the extent of 1 to 5 per cent. Later patent issues to him also cover the admixture of aluminum and manganese, as well as special processes of annealing aimed to secure the best characteristics for electrical use. Silicon-steel is very generally used to-day for transformer cores, and is made by several mills in this country. The proportion of silicon varies between 2.5 and 4.0 per cent., the exact percentage not being a matter of importance. The specific conductivity of this material is about one-fourth that of ordinary annealed steel, and the eddy current loss is reduced in the same proportion. The hysteresis loss is about two-thirds to three-fourths the value in ordinary transformer steel, which is another substantial gain.

Furthermore, the aging in silicon steel is negligible. By aging is meant the increase in core losses which occurs with time. The aging is usually accelerated by a rise of temperature, even the working temperature of the apparatus having an action of this kind. Specimens may be aged artificially by keeping them at a temperature of 100° C., a few weeks at that temperature being sufficient to bring out whatever tendencies of this kind may be inherent in the material. Sheets which have been subjected to heat treatment for the purpose of making them unusually soft, seem especially subject to aging, and much of the material formerly used for cores was very objectionable on this score. The speaker has tested electrical sheet steel in which the aging amounted to as much as 25 per cent. in 100 hours and

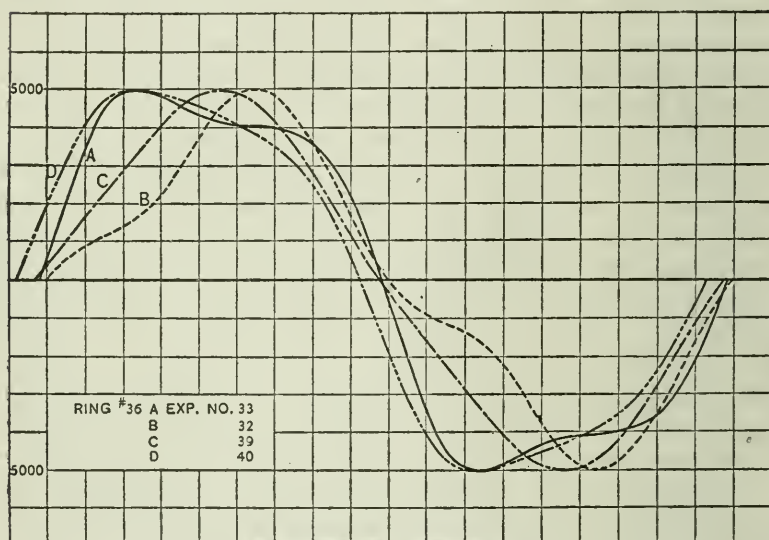
* J. F. Kelly, U. S. Patent No. 570310, October 26, 1896.

† R. A. Hadfield, U. S. Patent No. 745829, December 1, 1903.

67 per cent. in 500 hours, the material being maintained at 90–100° C. On the other hand, none of the silicon-steels tested has shown an increase of as much as 5 per cent.

Experiments have also been made looking toward the utilization of silicon-steel in the cores of generators and motors, but not with entire satisfaction. Silicon-steel has a high permeability in weak fields, making it especially suitable for series transformers, but its permeability falls off rapidly at high magnetizations, such as are found in the teeth of generator and motor

FIG. 7.



Form of waves of magnetic flux.

cores, and it is difficult to reach the necessary flux density. Moreover, the mechanical properties of this steel are a disadvantage, for it is hard and in a sense brittle. It rapidly dulls punches, dies and other cutting tools, and the dies used for generator and motor stampings are not so simple as those used for transformers. Where the metal is subject to continual vibration, it is in danger of breaking, and the teeth of the core have been known to snap off.

While no other alloy-steel has proved of such industrial importance in regard to its hysteresis value as silicon-steel, there

are other alloys which have interesting and useful properties. Tungsten steel, owing to its high coercive force, has been largely used for permanent magnets, especially where constancy is necessary, as in the magnets of measuring instruments. Since a high coercive force is accompanied by a large hysteresis loss, such alloys as this are most unsuitable for any purpose except permanent magnets. The value of the hysteresis loss varies with the amount of carbon present as well as with the tungsten, and Swinden⁷ has recently shown that the maximum hysteresis for an alloy with 3 per cent. of tungsten is obtained when the carbon amounts to 0.5 per cent.

Chromium steel has properties very similar to tungsten steel, and is used for the same purposes.

Various nickel-steels have been investigated, and some of them show remarkable properties. Hopkinson found that an alloy containing 24.5 per cent. nickel was non-magnetic at ordinary temperatures, but when cooled below 0° C. it became magnetic and remained so upon returning to room temperature. If heated to 600° C. it again lost its magnetic properties, and did not recover them without another cooling. The magnetic changes were thus irreversible with respect to temperature. The density of the material was also found to follow an irreversible cycle, having the value at room temperature of 7.97 Gm. per c.c. when in the magnetic condition, and 8.15 Gm. per c.c. when non-magnetic.

Other experimenters have since examined a large number of nickel-steels. Osmond found that an alloy with 29 per cent. nickel was non-magnetic. Barrett and Brown state that the addition of 5 per cent. of manganese to an alloy high in nickel will make it non-magnetic, although the addition of 5 to 8 per cent. of manganese alone to ordinary steel does not obscure its magnetism. Nagaoka and Honda worked with a series of nickel alloys of different composition, and found that with 25 per cent. Ni the alloy was almost non-magnetic. They also found a remarkable change in the dimensions of these alloys when magnetized. The phenomenon of magnetostriction is not new, it being well known that iron and steel lengthen, while nickel contracts in the direction of magnetization. The addition of

⁷ T. Swinden, *Electrician*, 1909, lxii, 830.

nickel to steel, however, produces an increased lengthening. Moreover, in iron the lengthening is accompanied by a lateral contraction, so that the change of volume with magnetization is very small. In the nickel-steels, however, it is relatively large, a 29 per cent. alloy giving the maximum effect, which was about 50 parts in one million for the fields used. Twenty-nine per cent. of nickel appears to represent a critical point in composition, as other physical properties showed peculiarities in this specimen, and with higher nickel content the temperature effects are reversible.

Hadfield found that a steel containing over 20 per cent. of manganese was non-magnetic, and the manganese can be reduced as low as 7 per cent. when 2 to 8 per cent. of aluminum or silicon is added.

A non-magnetic steel is also obtained by alloying 17 per cent. of aluminum with iron. The explanation of all of these non-magnetic steels is probably that the temperature of transformation lies below ordinary temperatures.

Alloys of arsenic, of antimony and of bismuth with electrolytic iron have recently been investigated by Burgess.⁸ A 2 per cent. bismuth alloy showed high permeability, although bismuth is itself diamagnetic. The alloy containing 3.86 per cent. of arsenic not only showed high permeability, but the hysteresis was only about one-half that for Swedish iron.

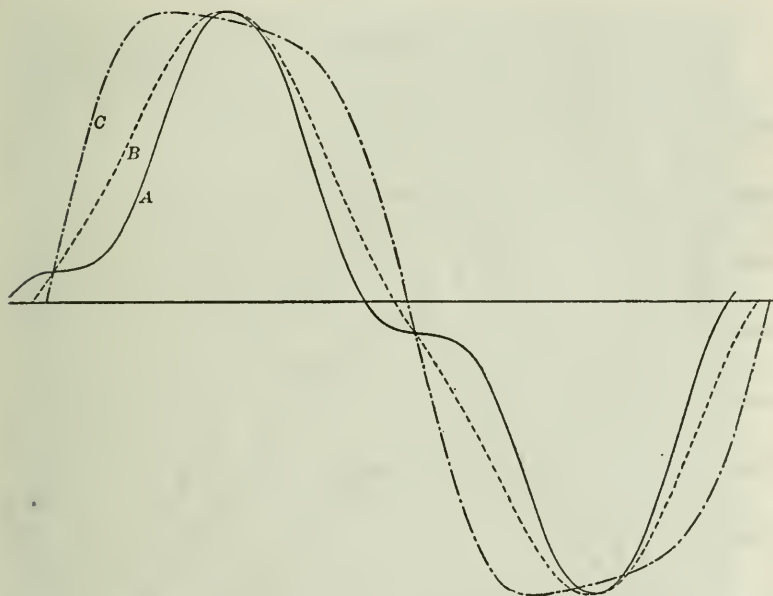
Of equal interest with the non-magnetic nickel-steels, and of great importance in the theory of magnetism, are the magnetic alloys of non-magnetic metals. Foremost among these are the Heusler alloys, composed of aluminum, copper and manganese. It was at first supposed that the best combination was obtained when the manganese and aluminum entered in the ratio of their atomic weights, *i.e.*, about two to one, but the later work of Preusser⁹ has shown that the most magnetic alloys are obtained with 12 to 13 per cent. of aluminum, regardless of the percentage of manganese. The earlier idea that the copper acted simply as a solvent or carrier for a definite combination of the other two metals has consequently been abandoned, and it is now believed that the copper plays an important rôle.

⁸ C. F. Burgess and J. Aston, Trans. Am. Electrochem. Soc., 1909, xv, 369.

⁹ W. Preusser, Thesis, Marburg, 1908.

The hysteresis of the Heusler alloys is not markedly different from that of iron. The values vary with the composition and heat treatment. Annealing from an appropriate temperature will greatly decrease the hysteresis, while other treatments may result in an enormous increase.¹⁰ Alloys of copper and manganese with tin, with arsenic and with antimony are also ferromagnetic, but to a less degree than those just considered.

FIG 8



Form of waves of magnetic flux.

Most of the salts of the magnetic metals show themselves to be paramagnetic but the permeabilities are very small. A few of the compounds of iron, however, show ferromagnetic properties. Thus the mineral magnetite, which is an oxide of iron, was the original lode-stone, and its hysteresis has been measured. Berndt¹¹ has found that ferric oxide and hydroxide exhibit marked hysteresis. The mineral pyrrhotite has received much attention from Weiss, who has shown that crystals of this

¹⁰ Knowlton and Clifford, *Phys. Rev.*, 1910, xxx, 125.

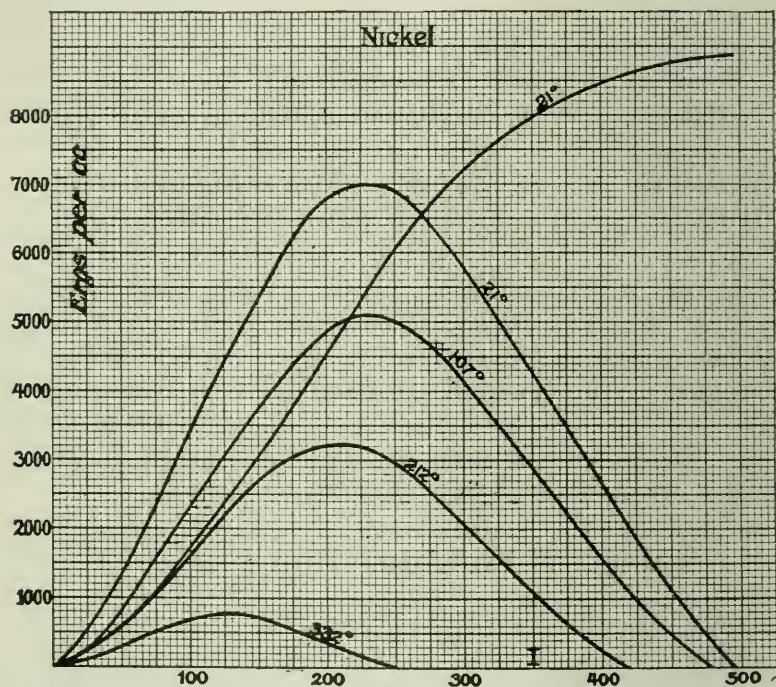
¹¹ G. Berndt, *Phys. Zs.*, 1908, ix, 750.

material, which is a higher sulphide of iron, Fe_7S_8 , are magnetic along one axis but not in a direction normal to this axis.

There are a large number of conditions which may affect the value of hysteresis in a given specimen, but time will not permit me to go fully into all of these, and I can but mention some of them.

Subjecting a specimen to mechanical stress will alter the

FIG. 9.



Rotary hysteresis at different temperatures. The curve for alternating hysteresis is given only for the temperature of 21°.

magnetic constants, the hysteresis usually being increased. If the stress be sufficient to permanently distort the metal, the hysteresis is permanently increased. Thus, any mechanical treatment, such as hammering, rolling, wire-drawing, etc., which mechanically hardens the specimen, will also harden it in the magnetic sense. The permeability is decreased and the hysteresis increased. The tempering of steel has a similar effect. Annealing, on the

other hand, will generally improve the magnetic qualities. Mechanical vibration has a marked effect on the hysteresis, as the molecular aggregations seem thereby to have greater freedom of adjustment, and follow more closely the magnetizing field. Not only does the previous mechanical treatment and heat treatment affect the magnetic quality, but the previous magnetic treatment will also have its influence upon the measured values, and a definite magnetic condition is best obtained by demagnetizing from a high flux-density.

When a point-by-point method of tracing the hysteresis loop is used, it is found that the shape of the curve depends upon the size of the steps used. This is attributed to "magnetic viscosity," and it has been shown that the changes in the magnetic flux continue after the changes in the magnetizing field have ceased.

It might be expected from this, that when magnetization is by means of alternating current, the hysteresis would be found to be dependent upon the frequency and the wave-form of the current used. Many investigators have experimented upon this subject, but the results are not concordant, and much of the work is vitiated by disturbing factors and insufficient precautions. The effect of frequency is still an open question. Some work by the writer a few years ago showed that there was a slight effect of wave form upon the hysteresis, though too small to be of any industrial importance even with very marked distortion of the wave.¹² The hysteresis is greater with a flat wave of flux than with a peaked wave, even though the maximum value of the flux is the same. If the wave be dimpled, the increase is much more marked, as a small loop is superposed upon the main loop. Figs. 7 and 8 show some of the wave forms used. The maximum flux in these experiments was determined by measuring the average value of the induced voltage.

The effects of temperature upon hysteresis constitute a somewhat complex group of phenomena. I have already referred to the permanent effect of subjecting magnetic material to higher temperatures—an effect which is made manifest when it returns to room temperature, and is known as aging. I want now to refer briefly to those effects which accompany a change of tem-

¹² The details of this work are given in Reprint No. 106 from Bull. of B. S., vol. v.

perature, but persist only while the new temperature is maintained. These effects are usually covered by the term temperature-coefficient.

While the variation of permeability with temperature has received much attention, data concerning the variations of hysteresis are not so plentiful. Many of the results published are concerned with the variations in hysteresis in a constant field and are consequently obscured by the variations in permeability. The

TABLE III.—EFFECT OF TEMPERATURE ON HYSTERESIS.

Material	Bmax.	Ergs per c.c. per cycle					Authority
		15°	100°	300°	500°	700°	
Iron.....	4000	1080	975	685	460	250	Wills
Iron.....	6000	2200	2200	1450	725	...	Wills
Tungsten steel (4.5 per cent.)...	2000	9200	8900	5800	2200	...	Wills
Tungsten steel (4.5 per cent.)...	6000	12000	11700	8000	3750	...	Wills
		-70°	20°	100°			
Soft wrought iron.....	2000	423	397	333	....	...	Thiessen
Soft wrought iron.....	5000	1720	1620	1520	....	...	Thiessen
Soft wrought iron.....	10000	5070	4600	4030	....	...	Thiessen
		-52°	17°	99°			
Crescent tool steel.....	14700	33850	31880	29600	....	...	Thiessen
		-65°	24°	100°			
Nickel steel (5 per cent.).....	14900	43070	41860	39700	....	...	Thiessen
		20°	270°	275°	290°		
Swedish iron.....	3500	2690	2080	....	....	...	Kunz
Wrought iron.....	3500	3100	....	2270	....	...	Kunz
Annealed charcoal iron.....	3500	2350	....	....	1600	...	Kunz

more recent researches have usually been conducted with definite flux-density, so that the results may be immediately interpreted.

Fleming and Dewar¹³ made measurements upon Swedish iron down to the temperature obtained with liquid air, but found no variation with temperature, and their results were confirmed by Claude.¹⁴

¹³ Fleming and Dewar, Proc. Roy. Soc., 1896, lx, 81.

¹⁴ G. Claude, C. R., 1899, cxxix, 409.

Kunz,¹⁵ working up to 800° C., found little change in steel up to 300° , but above that point there was a decrease. Soft iron, however, showed a steady decrease from room temperature up, the variation being linear. Some of his results are given in Table III. Wills¹⁶ found similar effects with iron and tungsten-steel, and Thiessen¹⁷ observed the same general trend for several materials between -70° and boiling water.

The work of Honda and Shimizu, reaching down to the temperature of liquid air, is perhaps the most illuminating which has been done on this subject. They found¹⁸ that upon cooling Swedish iron the hysteresis decreases for low flux-densities, but increases for high flux-densities, and tungsten-steel behaved in the same way. In nickel and cobalt, the hysteresis was always increased by cooling. A recent research by Waggoner¹⁹ shows that low-carbon steel behaves as stated just above for iron, while high-carbon steel behaves like nickel and cobalt. The change was least for a steel containing 1.1 per cent. carbon. He also found that the ratio of hysteresis to coercive force was constant for varying temperature and varying carbon content.

If instead of using a field which simply alternates in direction, we subject the magnetic specimen to a rotating field, such as may be produced by polyphase currents, a somewhat similar effect is produced, although the conditions are different. The material is now constantly magnetized, the field never being reduced to zero value, but the direction of magnetization is continually changed. Here again there is a lag of magnetization behind the magnetizing field, but the lag is a lag in direction, not in magnitude. This rotary hysteresis requires an expenditure of energy, as in the other case, but the amount of energy transformed is not the same, for a given value of the maximum flux-density. Eddy currents are produced in this case, also, and aid the transformation of energy into heat, but in what follows it is the energy due to the hysteresis that is to be considered. As in the case of the alternating field, the two sources of energy

¹⁵ W. Kunz, *Electrot. Zs.*, 1894, xv, 194.

¹⁶ R. L. Wills, *Phil. Mag.*, 1903, v, 117.

¹⁷ A. H. Thiessen, *Phys. Rev.*, 1899, viii, 65.

¹⁸ K. Honda and S. Shimizu, *Proc. Tokyo Phys.-Math. Soc. II*, 1904, iii, 186.

¹⁹ C. W. Waggoner, *Phys. Rev.*, 1909, xxviii, 393.

loss can be distinguished by taking observations at two different frequencies.

The hysteresis in a rotating field was first observed by Baily,²⁰ who showed in 1894 that if a magnet was rotated about an iron armature, the latter experienced a torque in the direction of rotation. The armature used was finely laminated, in order to avoid eddy currents as far as possible.

The torque was measured by balancing it against a spring, and the hysteresis was thus determined. The hysteresis was found to increase with the flux density in moderate fields, but finally reached a maximum and decreased to zero when the field was made sufficiently intense. This result was obtained with both soft iron and hard steel, and was a confirmation of Ewing's theory, which explains magnetic phenomena by the mutual action of the elementary magnets which must be regarded as constituting a magnetic substance.

Beattie²¹ made similar experiments upon nickel and cobalt, with similar results. In nickel, a maximum hysteresis loss of nearly 10,000 ergs per c.c. per cycle was observed with a magnetizing field of 340 gaussess. In cobalt a maximum of about 36,000 ergs per cycle was observed and in both cases the plotted curves indicated that the hysteresis would reach zero if the flux were carried to the saturation value.

Beattie and Clinker²² found that for iron the hysteresis reached a maximum for flux-density of 16,000 gaussess, and then decreased reaching zero at about 25,000 gaussess.

Schenkel²³ experimented by rotating the specimen in a steady field, and measured the torque by a form of transmission dynamometer. His results were similar to the above.

In 1908, Weiss and Planer²⁴ conducted some experiments with a rotating magnet which were somewhat more refined than the previous work. The specimens were in the form of disks, and when placed horizontally were subjected to a rotating field, but when placed vertically the effect was the same as an alternating field. Observations were made upon steel, iron, nickel, and

²⁰ F. G. Baily, *Electrician*, 1894, xxxiii, 516.

²¹ R. Beattie, *Phil. Mag.*, 1901, i, 642.

²² R. Beattie and R. C. Clinker, *Electrician*, 1896, xxxvii, 723.

²³ M. Schenkel, *Electrot. Zs.*, 1902, xxiii, 429.

²⁴ *Journ. d. Phys.*, 1908, vii, 5.

pyrrhotite. They found, like previous observers, that for low fields the hysteresis was greater in the rotary field than in the alternating, but after passing a maximum the hysteresis in the rotating field finally decreased to zero as the material reached saturation. The ratio of rotary to alternating hysteresis was found to be largest for the weakest fields, and had a value of 3.6 for nickel. This ratio decreased continuously as the field was increased, except in the case of steel, where it at first increased and then decreased.

During the past year two researches have appeared showing the variation of rotary hysteresis with temperature.

Fuller and Grace²⁵ used two-phase alternating current to produce the rotary field, while Perrier²⁶ used apparatus similar to that of Weiss and Planer at Zurich. Both used electric heating coils to obtain the higher temperatures. Some of the results of Perrier are shown in Fig. 9.

Both sets of experiments show that the maximum hysteresis in the rotary field decreases with increasing temperature, and that this maximum is reached with a lower flux-density. Thus for iron at 580° this maximum occurs at 10,500 gaussess, while at temperatures below 340° it occurs at about 16,000 gaussess. Since the saturation value is also reduced by increasing the temperature, it was to be expected that the hysteresis would decrease to zero for a lower magnetization and this was found to be the case.

Perrier worked with nickel, magnetite and three kinds of iron and concluded that the ratio of the maximum values of the two kinds of hysteresis was characteristic of the material and independent of the temperature.

²⁵ W. P. Fuller and H. Grace, *Phil. Mag.*, 1909, xviii, 866.

²⁶ A. Perrier, *Thesis*, Geneva, 1909.

THE PHYSICAL PRODUCTION OF LIGHT.

BY

EDW. P. HYDE.

*(Presented at a Stated Meeting of the Section of Physics and Chemistry, held
Wednesday, March 16, 1910.)*

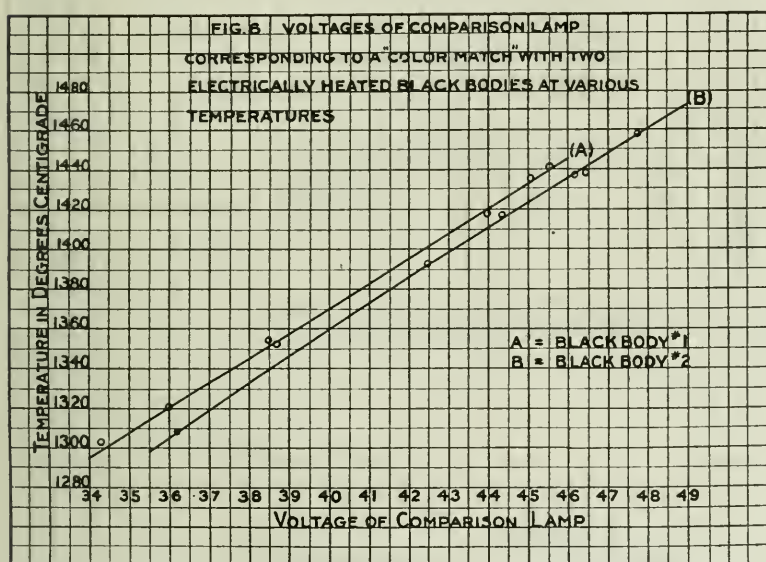
(Concluded from Vol. CLXIX, page 466.)

The first measurements on the black bodies consisted in determining the temperature of the black bodies at which they matched in color the standard carbon lamp at 75 volts. This was done by bringing the black body to various temperatures in the proper neighborhood and determining the voltage of the standard lamp corresponding to a color match. The accuracy with which this can be done is shown in Fig. 6, in which, however, the voltages refer to an auxiliary comparison lamp which when at 44.15 volts matched in color the standard carbon lamp at 75 volts. The results obtained on the two black bodies are given. For some reason the two black bodies though constructed in the same way and measured for temperature by thermocouples calibrated in the same laboratory, gave a difference in temperature of about 8° C. This difference may be due to the black bodies themselves, or possibly to variations in the comparison lamp. The latter assumption seems improbable since the comparisons with the two black bodies were made at about the same time. Moreover, computations for color match made from spectrophotometric comparisons of the standard lamp and black body No. 2 at the following temperatures, 1318° , 1335° , and 1432° C.,* gave respectively 1408° , 1414° , and 1417° C., with a mean of 1413° C. (1686° absolute) which agrees excellently with the value of 1412° C. read from the plot. It was impossible to carry the black body up to a sufficiently high temperature to match the

* Throughout this paper, unless specifically stated otherwise, temperatures will be given in Centigrade degrees on the ordinary scale, to which 273 must be added to obtain the absolute temperatures, which enter in the various black-body laws.

standard lamp at its next higher voltage, 100 volts. Having determined that the color of the standard lamp at 75 volts was the same as that of a black body at 1416°C . (mean of two black bodies) the next step was to determine the change in candle-power of the black body for 1 per cent. change in energy. This was done by measuring on a Lummer-Brodhun photometer set at a fixed distance from black body No. 1 the change in illumination produced by a restricted area of the rear wall of the black body when the latter was changed in temperature by a definite

FIG. 6.



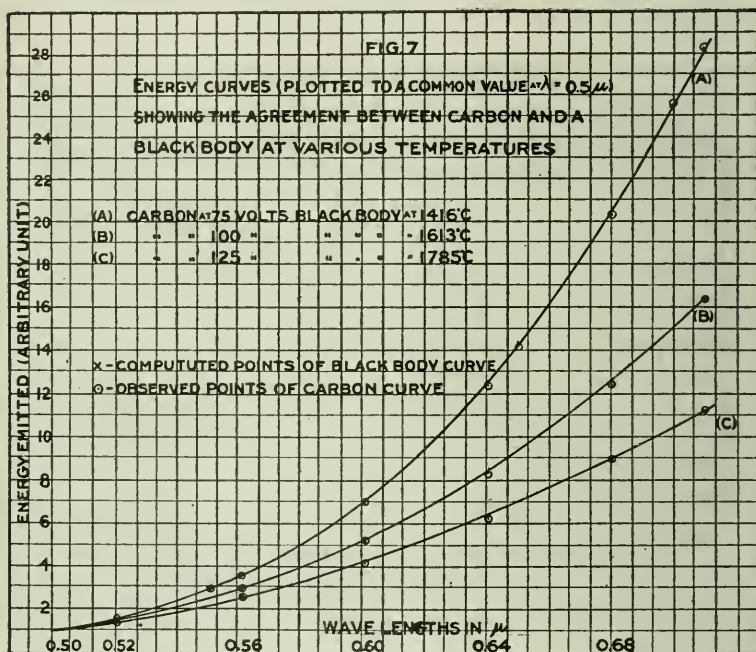
amount, measured by means of thermocouples. The increase in illumination, which is proportional to the increase in candle-power, was measured directly by varying the distance of a standard lamp; the increase in watts was computed from the temperature measurements by the use of the Stefan-Boltzmann law. The average value obtained by this method is given in Table II, opposite "Black body, observed."¹³

This coefficient obtained experimentally was checked by a direct computation on the assumption of the Wien equation of spectral energy distribution, and of Koenig's luminosity curves.

Although this method may conduce to large errors in the computation of absolute candlepower it is reasonably accurate for determining small changes in candlepower corresponding to some definite change in total emission, *i.e.*, some definite change in temperature.¹⁴ The value for the coefficient obtained in this way is given in Table II, opposite "Black body, computed."

As was mentioned just above in connection with the measure-

FIG. 7.



ments on the black body, and also previously in the general description of the two new photometric methods, the color match criterion for agreement in relative energy distribution in the visible region of the spectra of two sources, was only trusted after having been duly justified by numerous spectrophotometric comparisons. Of the various substances investigated, as given in the first columns of Tables II to IV, all were examined spectrophotometrically with the exception of the "Helion" filament, which appeared so similar to carbon¹⁵ as to make such a compari-

son unnecessary. Carbon was compared directly against black body No. 2 and showed no evidence whatever of excessive emissivity in any wave-length as compared with the black body. At the voltage of the carbon lamp corresponding to a color match with the black body at a given temperature the two spectrophotometric curves were identical throughout the entire visible spectrum to within the limits of accuracy of the measurements which was probably less than 2 per cent.

In Fig. 7, curve *A*, is shown the agreement in the two curves (coincident to within observational errors), for the black body and the carbon when at a color match with the standard lamp at 75 volts. The black body curve is computed for a temperature of 1416° C. from the Wien equation using the value $C_2 = 14500$. The carbon curve is the mean observed curve from the direct measurements against the black body at the three temperatures of 1318° , 1335° and 1432° C. assuming for the black body at each temperature the energy distribution given by the Wien equation. Whether or not 14500 is the correct value for the constant C_2 , indeed whether or not the Wien equation is the correct expression for the spectral energy distribution of a black body is of no consequence in affecting the conclusion that at least at moderately low temperatures the visible spectrum of carbon can be very accurately represented by the visible spectrum of the electrically heated Lummer & Kurlbaum black body at some definite temperature.

Nichols¹⁶ and Blaker¹⁷ had found evidence of a depression in the red region of the energy curve of carbon, when compared with acetylene. This naturally led to a direct comparison of acetylene against the carbon lamp which had been previously compared with the black body. The result was to show evidence of an emission band at the extreme red end of the spectrum of the acetylene flame. The actual spectrophotometric curve obtained is not given because there was uncertainty as to the magnitude of the effect which was in a region of the spectrum difficult to measure. Further experiments were not made, owing to the writer's resignation from the Bureau of Standards. Moreover, the urgency of such further experiments was greatly lessened by the confirmation of the general conclusion regarding the emission band in the deep red region of the spectrum of acetylene which the writer had discovered as a result of an

analysis of the spectral energy curves of acetylene determined by Stewart.¹⁸ The measurements of the flat acetylene flame indicated that the distribution in the visible spectrum is approximately that of a black body at about 2050°C .

Having shown that carbon exhibits no bands of pronounced emission in the visible spectrum, spectrophotometric comparisons were made between carbon and the other filaments when operated at the voltages determined for a match in color. These measurements gave no evidence whatever of pronounced selective emission in the visible spectrum of any of the substances examined. The spectrophotometric curves were perfectly smooth and in entire agreement with the curve for carbon, to within the errors of observation. In all of these measurements a "substitution" method was employed.

The absence of any indication of band emission in the visible spectrum of any of the metals examined would suggest as an interesting investigation a study of the reflectivity of tantalum, tungsten and osmium at various temperatures. Both tantalum and tungsten can now be obtained in strip form making possible such an investigation.

As stated previously, it was not feasible to operate the available black body at a sufficiently high temperature to compare its spectrum directly with that of carbon at the next arbitrarily chosen voltage of 100 volts. The next best thing to do was to compare spectrophotometrically the visible energy curve of carbon at 100 volts with its known curve at 75 volts and to compute from this derived curve the temperature which a black body should have in order to most nearly agree with the observed curve for carbon. Thus the temperature was computed (using Wien's equation with $C_2 = 14500$) at which a black body would emit the same relative energy at $\lambda = 0.7\mu$ and $\lambda = 0.5\mu$ as was observed for the carbon lamp. The complete visible energy curve of the black body at this temperature was then plotted and compared with the observed curve of carbon. These two curves (drawn in coincidence) are shown in Fig. 7, curve *B*, the temperature determined for the black body being 1613°C . The accuracy of this computed temperature is not insisted upon owing to certain errors which may enter and need correction in deducing relative energy curves from spectrophotometric observations when the luminosity curves of the two spectra under comparison

are different. The writer hopes to be able to publish a theoretical and experimental discussion of this question in the near future.

In a similar way the visible portion of the energy curve of the carbon lamp at 125 volts was determined by spectrophotometric comparison with the energy curve of the same lamp at 100 volts, and the temperature of the black body which would give a similar distribution was computed to be 1785° C. The observed curve for the carbon lamp and the computed curve for a black body at approximately 1785° C. are given in curve C, Fig. 7.

Having determined that carbon exhibits no marked emission bands in the visible, but rather conforms quite closely to the curve of a black body at both 100 volts and 125 volts, the other lamps were compared spectrophotometrically with the carbon lamp. None of these showed any marked deviation from carbon, but there was slight evidence in the case of osmium that the curve of the latter when showing the same relative distribution between the energy emitted at 0.7μ and that emitted at 0.5μ as compared with the carbon, dropped a little below that of the carbon at intermediate wave-lengths. This effect, which was so small as to lie almost within the errors of measurement was confirmed by the observation of the impossibility of making a perfect color match at high temperatures between carbon and osmium in the Lummer-Brodhun photometer. The osmium was relatively a little purplish, and the carbon a little greenish. For the other lamps, the effect, if present, was too small to be observed. Reference will be made to this phenomenon in a later paragraph.

It was, therefore, possible at the various temperatures at which measurements were made, and for all the lamps studied to secure color matches corroborated by spectrophotometric measurements with the possible slight exception noted above. Moreover it was possible at every voltage of the carbon lamp to find a black-body temperature at which the computed black-body curve was in agreement in the visible spectrum. Therefore, any selectivity which exists is not to be found in a pronounced emission band within the visible spectrum, but rather as a suppression or elevation of the visible spectrum as a whole compared with the infra-red region. It is to this form of selectivity that the two photometric methods apply. The data obtained by these two methods is contained in Tables II to IV.

In the first column of Table II, which contains the results obtained at a color match with the standard lamp at 75 volts, are given the various substances investigated. The second column contains the ratios (k) of the percentage change in candlepower to the percentage change in total energy radiated (taken as equivalent to the watts supplied). The third column contains the relative values of k expressed in terms of the value of k for untreated carbon as unity. By expressing the results in this way the relative differences among the different types of lamps are more readily seen.

TABLE II.

— Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 75 volts (black body at 1689° absolute).

Substances Investigated	k^* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed	3.5	1.00	....	....
{ Computed	3.6	1.04	....	....
Untreated carbon.....	3.45	1.00	0.39	1.0
"Helion" lamp.....	3.45	1.00	0.38	0.95
Flashed carbon.....	3.35	0.97	0.41	1.05
Metallized carbon.....	3.4	0.98	0.41	1.05
Platinum.....	3.1	0.89	....	....
Tantalum.....	3.0	0.86	0.50	1.3
Tungsten.....	2.85	0.82	0.59	1.5
Osmium.....	2.85	0.82	0.72	1.85

* k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k=1$ for untreated carbon.

In the fourth column are given the lumens per watt, on the basis of the *international candle*, and in the fifth column are given the same quantities expressed in terms of the value for the untreated carbon lamp taken as unity. Tables III and IV contain similar data at the higher temperatures corresponding to a color match with the standard carbon lamp at 100 volts and 125 volts respectively.

The results are quite interesting. Thus it will be noticed (Table II) that when these various substances have the same distribution of energy in the visible spectrum the lumens per watt range from 0.39 to 0.72 in absolute value, or from 1.00 to 1.85 relatively.

If there were no relative selectivity, the lumens per watt would be the same for every type. There is marked evidence, therefore, that there is considerable selectivity among the different types of filaments, and it is interesting to note the order in which the filaments arrange themselves. A higher value of lumens per watt, as for example the value 1.85 for the osmium lamp as compared with 1.00 for the untreated carbon filament, indicates that when the osmium filament has the same distribution of energy in the visible spectrum as the untreated carbon filament, the spectral energy curve of the osmium filament drops off con-

TABLE III.

Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 100 volts (black body at 1886° absolute).

Substances Investigated	k^* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed .....	.....	.....	.....	.....
{ Computed	3.25	1.06	.....	.....
Untreated carbon	3.05	1.00	1.5	1.0
"Helion" lamp	3.0	0.99	1.5	1.0
Flashed carbon	3.0	0.98	1.6	1.1
Metallized carbon	3.0	0.99	1.55	1.05
Platinum	2.75	0.90	.....	.....
Tantalum	2.6	0.86	1.7	1.15
Tungsten	2.55	0.84	2.0	1.35
Osmium	2.5	0.83	2.35	1.55

* k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k=1$ for untreated carbon.

siderably in the infra-red as compared with the energy curve of the untreated carbon. In other words, the osmium radiates selectively in favor of shorter wave-lengths, that is, in favor of the visible spectrum, and is therefore a more efficient luminous radiator than an untreated carbon filament. It would appear from the table that the "Helion" lamp is, if anything, less selective in favor of shorter wave-lengths than the untreated carbon. The small difference, however, between 1.00 and 0.97, may be accounted for by experimental error, so that we might say that the "Helion" filament behaves very much like the untreated carbon filament. It should be explained, however, that the "Helion" filaments which were used in this investigation were

quite old and it is barely possible that the deposit of silicon had entirely disappeared and that we were simply studying the properties of the base carbon, which would readily explain the results obtained. The treated carbon and the gem filaments are more selective than the untreated carbon; the tantalum considerably more selective; the tungsten still more so; and finally, the osmium most selective of all. It is very striking that despite the relatively large experimental errors which may enter into these measurements, the filaments arrange themselves very closely in the same order of selectivity when we use the second method of determining selectivity as found by the first method.

TABLE IV.

Average values obtained on lamps of each type at voltages corresponding to a "color match" with the standard lamp at 125 volts (black body at 2058° absolute).

Substances Investigated	k^* (absolute values)	k (relative values)	Lumens per watt (absolute values)	Lumens per watt (relative values)
Black body { Observed .....	....	....	....	....
Computed	3.05	1.11	....	....
Untreated carbon.....	2.75	1.00	3.5	1.0
"Helion" lamp.....	2.7	0.98	3.6	1.0
Flashed carbon.....	2.65	0.98	3.7	1.05
Metallized carbon.....	2.75	1.00	3.7	1.05
Platinum.....	....	....	....	....
Tantalum.....	2.35	0.86	3.9	1.1
Tungsten.....	2.4	0.88	4.4	1.25
Osmium.....	2.4	0.87	4.9	1.4

* k is the per cent. change in candlepower corresponding to a change of 1 per cent. in watts. The relative values are in terms of $k=1$ for untreated carbon.

Thus, in the second and third columns, the ratios of the percentage change in candlepower to the percentage change in watts is about the same for the untreated and for the "Helion" filaments. It is slightly less for the treated carbon and the gem filaments, and considerably less for platinum; somewhat less for the tantalum; and still smaller for the tungsten and osmium filaments. The only apparent discrepancy is that the tungsten filament has a lower coefficient than the osmium which is the reverse of what we found by the other method. This might readily be accounted for in two ways. In the first place, the

coefficients as given in the second and third columns are in no way as widely different as the values of lumens per watt given in the fourth and fifth columns, and a slight error in determining the coefficient might account for the difference in the relative results obtained by the two methods for the tungsten and osmium filaments.

In the second place, so far as I can see now, there is no definite reason why the relative quantitative results obtained by the two methods should be the same; for, granting that two filaments are selective as compared with a black body, the nature of the selectivity may be different. Thus, it may be that the energy curve of one filament is suppressed throughout the entire infra-red spectrum to approximately the same extent, whereas it may be that in the case of the other filament, the suppression may be exaggerated in some particular region of the infra-red spectrum. Such differences would seem sufficient to account for small quantitative differences in the selectivity as determined by the two methods.

The results obtained at the higher temperatures (Tables III and IV) are quite similar to those found at the lower point. By both methods the filaments arrange themselves in the same order as found at 75 volts, but the numerical differences are in some cases considerably smaller. Thus, at 75 volts, the lumens per watt of the osmium lamp is almost twice that of the untreated carbon lamp, whereas at 125 volts, it is less than one and one-half times that of the untreated carbon lamp.

Special attention should be called to the positions of the black body and platinum compared with the other substances studied. As was to be expected, the black body stands at one end of the list, all of the metals and carbon being selective with respect to it. There is considerable difference between the observed and computed values of " k ," but this is only to be expected. The electrically heated hollow enclosure is not a *perfectly* black body; the determination of the true temperature by the use of thermocouples is fraught with difficulties; the exact form of the formula for the spectral energy distribution is not established beyond dispute, nor are the exact values of the constants known; finally, with the experimental difficulties on the one hand, and on the other, the uncertainty introduced in the computation by the necessary introduction of sensibility curves of the eye, it is

easy to account for the difference found between the observed and the computed values of " k ." On account of this uncertainty, particularly at the higher voltages where it was impossible to make an experimental determination of " k ," the values in the third column of each table are expressed in terms of the untreated carbon taken as unity, rather than in terms of the black body. The computed values of " k " for the black body at the higher temperatures are subject to more doubt than that given in Table II for the lower temperatures on account of the uncertainty of the temperature of color match at the higher voltages, as explained in a previous paragraph.

There is especial interest in the results obtained with platinum. As seen from Tables II and III it would appear to be less selective than any of the three metals, tantalum, tungsten and osmium, and yet it has ordinarily been referred to in much of the literature on the subject as being one of the most non-black metals. It is true that this departure from blackness may lie in its low emissivity and not in its selectivity, since it is known to emit but a small fraction of that radiated by a black body at the same temperature. This uncertainty as to what is meant in referring to a departure from blackness emphasizes the practical need of the distinction insisted upon in this paper between mere grayness and selectivity. So far as I know, the emissivities of tantalum, tungsten and osmium have never been determined with any degree of accuracy.

It is to be regretted that with the platinum lamps available up to the present time it has not been possible to determine the lumens per watt owing to the large conduction losses at the leading-in wires. An effort is being made to obtain this data at the present time.*

At this point the author desires to emphasize the fact that the numerical values given should not be trusted to too high an accuracy, as some of the lamps were used for quite a long period and showed marked evidence of deposit on the bulb. The uncer-

* Since the completion of this paper, data on the lumens per watt of platinum has been obtained. In Table II the lumens per watt for platinum should be 0.44 (absolute values) or 1.1 (relative values). In Table III the corresponding values should be 1.55 (absolute values) and 1.05 (relative values). These values of the lumens per watt, though not as accurate for platinum as for the other lamps, are consistent with the values of " k " found for platinum as compared with the other filaments investigated.

tainty becomes greater, of course, as the temperature increases, since the disintegration of the filament proceeds much more rapidly at the higher temperatures. The voltages at which the carbon filaments were operated to match in color the standard carbon at 125 volts were well beyond the normal values for the lamps, while the metal filament lamps, even at the highest temperature used, were still operating below normal voltage. However, some of the tantalum lamps showed marked deposit.

That no serious error was caused, however, by the deterioration of the lamps is shown in two ways. First, the filaments arrange themselves in the same order at the highest temperature as they do at the lowest, when they were operating well below their normal working temperatures and had suffered no disintegration. Secondly, the coefficients of change in candlepower, corresponding to 1 per cent. change in watts would not be affected to any great extent by a deposit on the bulb, and in almost every case as pointed out before, the filaments arrange themselves in the same order by both methods.

The one method, that of determining the lumens per watt, is the more sensitive when the experimental conditions are very carefully determined. The other method, while less sensitive, is, at the same time, much less dependent on the experimental conditions. Slight blackening of the bulb, appreciable loss of energy by conduction at the leading-in and anchor wires, and the errors in the wattage of the filaments introduced by bad contacts between the leading-in wires and the filament, would probably make but little difference in the values obtained for the coefficient of change in candlepower corresponding to 1 per cent. change in watts. These errors would probably be insignificant compared with the marked differences between the coefficients of the untreated carbon lamp and those of the osmium lamp, for example. There can be little doubt but that the arrangement of the filaments given in Tables II, III, and IV is substantially correct, though the numerical values found as a result of a more extended investigation might be somewhat different.

In interpreting the results given in the tables it may be stated that there is relative selectivity among the filaments beyond any doubt, but to what extent the high efficiencies of the metallic lamps are to be ascribed to selectivity and to what extent to the high temperatures at which the filaments operate, is by no means

immediately apparent from the data given. In order to arrive at any definite conclusion in regard to the amount of the selectivity one must know under what conditions of operation the filaments are at the same true temperature and at present there is no ready means available for making this determination.

If one could assume that when the filaments are at the same color, that is, when they show the same distribution of energy in the visible spectrum, they are operating at the same temperature, a quantitative estimate of the amount of selectivity would be possible at once, but there is no reason to believe that when the filaments show the same distribution of energy in the visible spectrum, all of them are operating at the same true temperature; in fact, there is much reason to believe that under this condition they are not operating at the same true temperature. By making an assumption which has been found to be true for platinum and which, though probable for most metals, has not been demonstrated to be true, it is possible to form an idea of the direction in which the difference in temperature will occur and to place a lower limit on the effect of selectivity in partly accounting for the high efficiency of the metallic filament lamps.

It will be noted from the data given in Table II that when the untreated carbon and osmium filaments are at the same color the lumens per watt of the osmium filament are 1.85 times the lumens per watt of the untreated carbon filament. This means that relatively more of the energy emitted by the osmium filament lies in the visible spectrum than in the case of the untreated carbon filament and that, therefore, the osmium filament is probably radiating selectively in favor of the shorter wavelengths. The numerical value of the effect depends, however, on the relative temperatures of the two filaments. If they are at the same temperature, the osmium is almost twice as efficient as the carbon lamp when they are both at the same low temperature corresponding to a color match with the standard carbon lamp when operated at 75 volts. If, on the other hand, the temperature of the osmium filament is higher than that of the carbon filament, then one cannot tell whether the increased efficiency of the osmium lamp is due to its selective emission, or to the slightly higher temperature at which it is operating.

Our knowledge of platinum radiation would lead one to expect, however, that the temperature difference is in the opposite

direction. If we imagine a radiating body which tends to exaggerate in its emission the energy of the shorter wave-lengths, that is, a body which emits a larger proportion of its total radiant energy in the visible spectrum as compared with a black body at the same true temperature, it is probable that this property of selective emission would obtain in the visible spectrum also, so that the emission in the blue would be relatively larger than the emission in the red as compared with the emission from the black body at the same temperature. If this assumption, which would seem to be true for platinum, is true for tantalum, tungsten and osmium, then the values recorded in the tables give, in every case, the lower limit of the effect of the selectivity on the efficiency of the filaments. For if, when at the same true temperature, the osmium radiates relatively more blue than red as compared with the untreated carbon,—considered approximately as a black body,—the color of the osmium light would be bluer than that from the untreated carbon, and it would be necessary, in order to bring the light of the carbon filament to a color match with that of the osmium filament to increase the voltage, that is, to increase the temperature of the carbon lamp. Such an increase of temperature would increase the lumens per watt for the carbon filament, and if it is found that, even at a color match, the lumens per watt of the carbon filament are only a little more than one-half the lumens per watt of the osmium filament, it would seem that if the two filaments were at the same true temperature the difference in efficiencies would be even greater. Hence, the numerical values given in the tables would seem to indicate a lower limit to the effect of selectivity on the efficiency. It is impossible to say how much more pronounced the selectivity would be if one could bring the filaments to the same true temperature.

It is possible that the difference between the working temperatures when the filaments are at the same color becomes more pronounced as the absolute temperature is increased and that this may account for the smaller differences in lumens per watt at the higher voltages as compared with the results obtained at 75 volts. At all events, one can see from Tables III and IV that if the assumption contained in the previous paragraph is true, an osmium lamp at the same true temperature as that at which an anchored oval treated carbon filament operates when

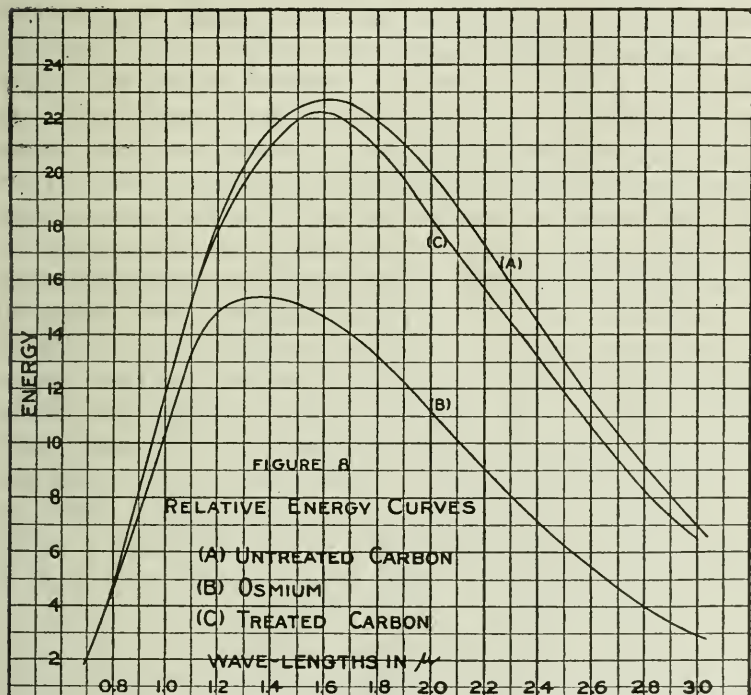
consuming about 3.1 watts per mean horizontal candle,—color match with standard carbon lamp at about 115 or 120 volts,—would show an efficiency higher than that of the carbon lamp by more than 35 per cent., or 40 per cent.; one cannot estimate how much higher the efficiency would be without a knowledge of the temperature difference which exists between the osmium and treated carbon filaments when at a color match.

From the data given in the tables for tantalum and tungsten, it is evident that for these, also, as well as for osmium, the selectivity would seem to play an important part in causing the high efficiency, particularly in the case of tungsten. It cannot be emphasized too greatly, however, that all of the deductions in regard to the effect of selectivity in partly explaining the high efficiency of the metallic filament lamps are based on the single assumption that if a black body and a metal are at such temperatures as to show the same distribution of energy in the visible spectrum (color match), the temperature of the black body is at least as high or higher than the temperature of the metal. This is true for platinum, the only metal that has been investigated, but the writer cannot say positively that it is true for other metals.

Reference has been made several times to the possible errors in the results owing (1) to the difference between the energy input and the energy radiated, and (2) to the changes in the lamps consequent upon burning, with the resultant deposit of carbon or metal on the bulb. The effect of each of these two sources of error has been considered, but it is desired to refer further to the first source enumerated in order to present an experiment of considerable interest as confirming the conclusions that had already been reached. Dr. Coblentz, of the Bureau of Standards, who, at the time of these experiments was engaged upon a study of the constant a for various substances, very kindly undertook, upon the request of the writer, to determine the infra-red energy curves of individual lamps of each of several types at stated voltages. The voltages which had been chosen were those for a color match with the standard carbon lamp (100 volts), as it was the desire of the writer to obtain from this experiment qualitative confirmation of the conclusion that if the infra-red curves of carbon and osmium, for example, were plotted to the same ordinate at the red end of the visible spectrum, say 0.7μ , the ordinates of the osmium curve would fall off con-

siderably in the longer wave-lengths. The results of the experiment for untreated carbon, treated carbon, and osmium, are shown in Fig. 8. Although the results of this experiment have already been published by Cady, Middlekauff and the writer,¹⁹ and have been included also in a paper by Coblenz,²⁰ they are given again here since the experiment logically forms a

FIG. 8.



part of the present investigation, in connection with which it was undertaken. By reference to the curves of the figure it is seen that the indications afforded by the lumens per watt in Table III is entirely confirmed not only qualitatively, but even approximately quantitatively. When the two filaments have relatively the same distribution of energy in the visible spectrum, the energy radiated in the infra-red by the osmium is only about two-thirds that emitted by the untreated carbon. Flashed carbon

is intermediate between the two, though not much different from untreated carbon.

Although it is not the intention to give here an elaborate discussion of the radiation laws as applied to metals, there is one further point of interest that is pertinent to the present investigation. It is easy to deduce on the assumption of the Wien equation that two lamps which have some definite candlepower relation when at a color match (rigorously, the same relative intensity at two wave-lengths) at a low voltage, must have the same candlepower relation at any other voltage. This conclusion results only if Wien's equation is assumed to hold with a constant or if the difference in α for the two temperatures is the same for the two lamps. This conclusion was tried with various lamps by comparing each with carbon on the photometer. Thus, placing the carbon at some low voltage, the other lamp, say tungsten, was brought to such a voltage that it matched in color the carbon lamp, as determined in the photometer. The photometer was set to a match in intensity and clamped. The voltage of the carbon lamp was then increased from say 75 volts to 125 volts, and the voltage of the tungsten lamp changed until there was an *intensity* match. The color was found to match that of the carbon as closely as could be determined. When the same experiment was tried with osmium, *versus* carbon, a quite appreciable color difference was evident at the high voltage. Moreover, as stated in an earlier paragraph, it was impossible to secure an exact color match at the high voltage, the osmium lamp at the best appearing relatively purplish, although this nearest match required a quite appreciable change in voltage from that which gave a match in intensity. Whether the radiation from osmium is unique, or only different in degree in its variation from the black body, remains to be determined.

In passing it is interesting to note that the experiment described above presupposes a certain relation among the α 's which would seem to point to a constancy in α in moderate changes of temperature. This is in contradiction to the results of the investigation by Coblentz and should hence receive further consideration.

V. RÉSUMÉ OF THE NEW PHOTOMETRIC METHODS AND RESULTS.

In summarizing the two photometric methods which have been discussed at some length there are two features to be emphasized: (1) the viewpoint which constituted the basis of the measurements, and (2) the extreme simplicity of the methods employed. The viewpoint consisted in comparing the radiating properties of various substances when brought to the same distribution of energy in the visible region of the spectrum. The method employed to secure this condition consisted merely in bringing the two sources to a match in color by the use of an ordinary Lummer-Brodhun contrast photometer. The two methods used in the study of the radiating properties under this condition consisted merely in determining the lumens per watt, and the ratio of the percentage change in watts. Except, therefore, for the work on the electrically heated black body as a reference point, and for the check measurements made with spectrophotometer and infra-red spectrometer, the entire investigation could be carried out with an ordinary photometer and adequate ammeters and volt-meters.

The viewpoint lying at the basis of the measurements is at the same time quite old and yet distinctly new. One of the oldest methods of pyrometry depended upon the color of the light as determined by eye observations without reference, however, to any standard; but this old method could lay claim neither to any high degree of accuracy, nor to any theoretical application to the study of the radiating properties of matter. Morris, Stroude and Ellis,²¹ 1907, made the blanket assumption that as a first approximation all filaments could be considered as of the same temperature when operating at the same color, but in the discussion apparently no special significance is attached to this point. Again in 1907 Leder,²² in studying the Hefner and osmium filament lamps, determined the temperature of the black body for equal distribution of energy in the visible spectrum, but instead of realizing the full significance of his results he argued an extremely high operating temperature of the osmium apparently on the ground of the low emissivity of all metals as compared with a black body. It is thus true that the black body temperature, as determined in the ordinary way with the customary optical pyrometers, is lower than the true temperature of the

body, but the equation of absolute emissivity does not enter when the method of comparison is by color match. In fact, the true temperature of the selective body is quite probably lower, rather than higher than the temperature of the black body when at a color match, in this way affording an upper limit of temperature, just as the ordinary methods of optical pyrometry afford a lower limit of the true temperature.

The results obtained by the application of the photometric methods show very interesting facts. All metals studied are selective, and, as would seem probable from the results, selective in the same way, *i.e.*, in favor of the shorter wave-lengths. All three of the metals, tantalum, tungsten and osmium, appear to be more selective than platinum, the osmium deviating farthest. On the basis of one assumption, which, though probable, is not necessarily true, the conclusion results that when at the same true temperature osmium is at least 40 or 50 per cent. more efficient as a luminous radiator than untreated carbon.

The limitation to the experimental methods as described thus far is found in the restriction to the study of substances which can be heated in a vacuum by the passage of an electric current. By the use of a surface bolometer (a special form of which is now being constructed through the courtesy of the Leeds & Northrup Co.) to measure directly the radiant energy, rather than depending upon the electrical power supplied, substantially the same general method may be employed in a more general way. It is hoped thus with some modifications to extend the measurements to a study of flames, gas mantles, and other forms of luminous sources.

REFERENCES.

- ¹ Charpentier, Sur les Phénomènes Rétiens, Rapports Congrès International de Physique, vol. iii, 523, Paris, 1900.
- ² Koenig, Gesammelte Abhandlungen zur Physiologischen Optik, Leipzig, 1903, 144, *et. seq.*
- ³ Koenig, *Loc. cit.*
- ⁴ Lummer and Kurlbaum, Verh. d. Phys. Ges. zu. Berlin, vol. xvii, 106, 1898.
- ⁵ Physical Review, vol. xxvii, 521, 1908.
- ⁶ Hyde, Cady and Middlekauff, Trans. Ill. Eng. Soc., vol. iv, 334, 1909; Electrical World, vol. liii, 439, Feb. 1909; Ill. Eng., London, vol. ii, 241, 335, 1909.
- ⁷ Waidner and Burgess, Preliminary Measurements on Temperature and Selective Radiation of Incandescent Lamps, Bulletin Bur. of Stds., vol. ii, 319, 1906. See also Holborn and Kurlbaum, Ann. der Physik, Ser. 4, vol. x, 236, 1903.
- ⁸ Paschen, Ann. der Physik, Ser. 3, vol. lviii, 455, 1896.

- ⁹ Coblentz, Bull. Bur. of Stds., vol. v, 339, 1909. See also Elec. World, vol. lii, 1345, 1908.
- ¹⁰ See Aschkinass, Ann. d. Physik., Ser. 4, vol. xvii, 960, 1905.
- ¹¹ This conclusion has been corroborated by Drysdale (see London Illuminating Engineer, vol. i, 27 *et seq.*, 1908) and Fery and Cheneveau (see Bull. de la Société Internat. des Electriciens, Series 2, vol. ix, 655, 1909), while Lux (see London Illuminating Engineer, vol. i, 98, 1908) has found quite appreciable differences between the energy in-put and that radiated.
- ¹² For a description of the type of electrically heated black body used, see Waidner and Burgess, Bull. Bur. of Stds., vol. i, 189, 1905.
- ¹³ See also Lummer and Pringsheim "Ziele der Leuchttechnik," Lummer, R. Oldenbourg, München and Berlin, 1903, p. 99. (From the data of Lummer and Pringsheim, the value of 3.65 is obtained by interpolation, which agrees very well with that given in the table.)
- ¹⁴ Practically this same method was employed by Eisler several years ago. See E.T.Z., vol. xxv, 188 and 443, 1904.
- ¹⁵ See *idem* for probable reason.
- ¹⁶ Phys. Rev., vol. xiii, 65, 1901.
- ¹⁷ Phys. Rev., vol. xiii, 345, 1901.
- ¹⁸ Phys. Rev., vol. xvi, 123, 1903.
- ¹⁹ *Loc. cit.*
- ²⁰ *Loc. cit.*
- ²¹ J. T. Morris, F. Stroude and R. M. Ellis, Electrician, vol. lix, 584, 1907.
- ²² F. Leder, Ann. d. Physik., Ser. 4, vol. xxiv, 305, 1907.

Radio-Activity of Potassium Salts. J. C. McLEANAN. (*Phys. Review*, 1909, 29.)—The radio-activity of potassium salts was investigated by the method in which one vessel is placed within, and insulated from, a second and the electrical charge which the insulated body or vessel more or less rapidly acquires is then observed. Preliminary experiments were made on the charging action of polonium, and that of the secondary rays excited in aluminum by the R-rays from radium; the charges acquired by uranium salts at low pressures were also observed. In the case of potassium salts the results show that in high vacua both potassium nitrate and potassium sulphate emit an excess of charged particles of the β -type. The effect observed was small in all cases and it required exceptional conditions to bring it into evidence. It was not found possible to decide whether any radiation of the α -type is emitted by the potassium salts or not.

Propagation of Flame by Coal-Dust in Mine Galleries. J. TAFFANEL. (*Comptes rendus*, 1909, 149.)—Tests made in the experimental mine galleries at Liévin show that when a gallery is partially blocked or when it exhibits a sharp bend, the violence of a coal-dust explosion undergoes considerable diminution. Further, when the partial stoppage of the gallery is effected by means of movable and incombustible materials, these are carried along by the gases preceding the explosive flame and exert a cooling action sufficient to prevent the further propagation of the combustion.

THE PHENOMENA OF FLOCCULATION AND DEFLOCCULATION

BY:

E. E. FREE.

*(Presented at a Stated Meeting of the Section of Physics and Chemistry,
held March 10, 1910.)*

(Concluded from Vol. CLXIX, page 438.)

THE EFFECT OF ORGANIC COLLOIDS ON SUSPENSIONS.

The other general class of bodies known to importantly influence flocculation is that which includes the organic colloids, typified by gelatin, dextrin, the albumins, etc. These have long been known to have a pronounced tendency to stabilize and prevent the flocculation of suspensions to which they are added. This is the commonest, and was for a long time the only, method of making and preserving the instable inorganic colloids. The various colloidal solutions of metals, colors, etc., which are now finding wide application in the arts and in medicine are almost all prepared and preserved in this way. This action is, however, more a passive than an active one. These bodies tend to keep apart, and suspended, particles already in a separate condition, but aggregates already existing in a suspension must be destroyed (by shaking or otherwise) in order to bring into play the stabilizing action. There is no evidence that these bodies (the colloids) have themselves any active tendency in breaking up aggregates or in decreasing the degree of flocculation. They are preventives of flocculation rather than deflocculators. Practically, of course, the result is the same. The shaking or stirring which usually accompanies the addition of the colloid to a suspension itself mechanically destroys a large proportion of the aggregates and the colloid then prevents the reflocculation which would otherwise take place.

It should be noted also that the colloids which show this stabilizing action belong exclusively to the fifth class of disperse systems as set forth in Table I. That is, they are liquid-particle

colloids (really very fine-grained emulsions), and consist of a suspension of very minute liquid particles in a liquid medium. The reason for the close limitation to this class of bodies will appear on examination of the mechanism of the action—in this case fairly well understood. In brief, what happens is that the particles of the original suspension are enveloped by a thin film of the colloidal material acting in accordance with the well-known surface tension laws in precisely the same way in which a drop of oil spreads itself out in a thin film on a water surface. This can obviously take place only when the colloidal particles are liquid and able to spread themselves out in thin films. It can also take place only when the relative values of the surface tensions demand it, and as these values vary for different substances, not all liquid-particle colloids can be expected to show the action in the same degree. Nor, indeed, do they. The stabilizing power of the various colloids varies greatly, and there are many such bodies which do not show it at all.

This leaves unexplained the reason why the surrounding film of foreign material should so effectively prevent flocculation, but the solution of this question must await a better knowledge of the causation of flocculation itself and the primary factors which influence it.

PRACTICAL BEARINGS OF FLOCCULATION.

In conclusion it may be well to indicate briefly some of the ways in which the phenomena we have been discussing are of practical importance in the laboratory and the factory. Lack of time forbids any detailed treatment, and indeed such treatment is hardly possible in the present state of knowledge. Certain empirical flocculators and deflocculators have been in use for years, but general principles have been lacking and are only now beginning to be discovered and applied.

The most obvious applications of the principles of flocculation are to the processes of precipitation, filtration, and the general handling of fine precipitates and of colloidal matters both technically and in the laboratory. For instance, an increase in the degree of flocculation will permit the collection by subsidence, or on a filter, of suspended matter which in its deflocculated state would be too slowly precipitated for one process and too fine-grained for the other. This is one reason why analysts

boil precipitates in order to collect them more easily,¹³ and why in other cases they add solutions of ammonium nitrate, nitric acid, and other flocculating agents. Technical applications are found in the collection of lime sludges from caustic tanks, in the "salting out" of colloids and emulsions, etc. Many other important technical applications are found in the processes of water purification and clarification, but this is a science in itself and cannot be discussed here.

A second important line of application is in the manufacture of permanent suspensions, colloidal and otherwise, and the use of deflocculating agents (mainly organic colloids) for this purpose has grown to enormous proportions. The ordinary liquid India ink, for instance, is simply a suspension of very finely divided lamp-black preserved by the addition of both organic colloidal matter and an alkali (usually ammonia). The various suspensions and emulsions used in medicine are similarly prepared and preserved. Preparations of permanently suspended "colloidal" silver and iron are now in general use by physicians. The most brilliant application in this field is, however, the celebrated deflocculated graphite of Mr. Acheson. By very fine grinding and by the use of tannin and other colloidal bodies, with or without alkalies, Mr. Acheson some time ago succeeded in keeping graphite in practically permanent suspension in water. Later he accomplished the much more difficult feat of suspending it in oil, thus producing an exceedingly valuable lubricant which is having wide application.

A third series of phenomena in which flocculation effects are of great importance is that of the plasticity of clays. Here the desideratum is the minimum of flocculation, and potters have for years been using two expedients, both of which we have seen to act in this direction—lowering of temperature and the addition of organic colloids. The latter in particular is of very ancient application. Straw and similar refuse (all containing colloidal material) have been customarily added to worked clay since the beginnings of industry.

The fourth great line of application, and the last of which I shall speak, is in the biologic reactions of coagulation, agglu-

¹³ Rise of temperature, as already noted, increases the degree of flocculation. The other reason for boiling is to obtain the increase of crystal size usually caused thereby.

tion, etc. These reactions are of high theoretical interest in connection with the mechanism of the vital processes, and are of great potential value to mankind. They are exceedingly complex, and, as yet, very little understood, but the best minds of the medical profession are being applied to their solution and light may be expected soon in this direction.

I have said nothing concerning the phenomena with which my own work in this field has been mainly concerned—flocculation in soils. These phenomena are so important agriculturally that they can hardly be left unnoticed, but as they include factors entirely foreign to the preceding discussion, I shall treat them separately in an appendix to this paper.

SUMMARY.

The present knowledge of flocculation phenomena, as outlined in this paper, may be roughly summarized as follows:

1. The phenomena of flocculation occur in "disperse" systems consisting of fine particles distributed through a medium and classifiable according to size of particle and to the physical state of the particle and the medium.

2. They are characteristic of these states of matter and not of any particular substance or substances.

3. Flocculation and deflocculation are but relative terms. The more exact concept is that of *degree of flocculation*.

4. This degree of flocculation is influenced by many factors of which the main are added substances of the following three classes: (1) Most acids and neutral salts which increase the degree of flocculation. (2) The stronger alkalies, which decrease the degree of flocculation. (3) Most organic (liquid-particle) colloids, which prevent increase in the degree of flocculation.

5. The action of salts, acids and alkalies is probably at least two-fold: (1) on the mutual interpenetration (solubility) of particle and medium; (2) on the electric charges on the surface of the particle.

6. The stabilizing action of organic colloids is due to the formation of thin films of the colloid substance about the suspended particles.

7. There are many applications of flocculation phenomena

to the handling of precipitates and suspensions, the preparation of permanent suspensions, the working of clay, certain biologic reactions, etc.

APPENDIX—FLOCCULATION IN SOILS.¹⁴

It is obvious that the kinds of flocculation phenomena discussed in the previous pages cannot be the main ones which occur in the soil. There is nothing to correspond either to the suspended particles or to the medium of suspension. The soil contains not only solids and liquids but gases as well. The phenomena at the gas-liquid surfaces must be taken into account, and indeed the surface tensions at these surfaces are really the controlling forces in soil flocculation.

The mechanism is as follows: In a moist, but unsaturated soil, the water exists mainly in the form of thin films about the soil particles. At the points where the solid particles touch each other these surrounding water films are also in contact, and when the soil is sufficiently moist the water-film system is continuous throughout its mass. The existence of these films was early recognized and their importance in controlling the movement of water through soils has long been appreciated. Only recently, however, has it been discovered that these films are of paramount importance in controlling the *structure* of the soil, and this is what mainly concerns us here.

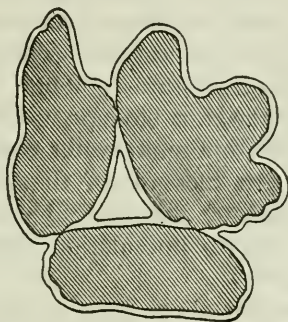
The conditions are shown in Fig. 6, which represents in cross-section three soil particles with their surrounding water films. At each point of contact the water films fuse, filling the wedge-shaped space between the particles and forming a curved surface such as represented diagrammatically in Fig. 7. From the well-known surface tension laws it is obvious that there will be a force tending to pull the sides of the wedge together, or, in the case of soil grains, to hold them together at each point of contact. This force at the fusion surfaces of the water films is the main cause of the formation and preser-

¹⁴ The facts and explanations here given are taken largely from Bulletin 50 of the Bureau of Soils, U. S. Dept. of Agriculture; "Moisture Content and Physical Condition of Soils," by F. K. Cameron and F. E. Gallagher (1908).

vation of aggregates in the soil.¹⁵ Without it there would be no flocculation.

The absolute values of these forces between the grains depend on the curvature of the water surface and it is obvious that this curvature will vary as the water surface retreats toward

FIG. 6.



Cross-section of soil grains showing surrounding water films.

or advances from the point of solid contact—that is, as the water films generally decrease or increase in thickness. Such changes in the water films are brought about by changes in the water content of the soil, and this is the reason for the great influence of moisture content upon the degree of soil flocculation. If a soil be so dry that the water films which do exist

FIG. 7.

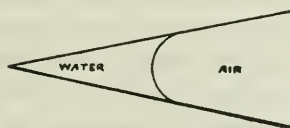


Diagram of water-film surface in a wedge-shaped space.

are not generally in contact with each other, the surface tension forces will not exist and the soil structure will be controlled by gravity alone. If, on the other hand, the soil be saturated or nearly so, the interstitial spaces will be entirely filled with water, the gas-liquid surfaces and their tensions will disappear,

¹⁵ The chemically cemented aggregates which occur in some few soils are, of course, excluded from consideration.

and the structure of the soil will again be controlled in the main by gravity. It is apparent, therefore, that the activity of the water films, and therefore the degree of aggregation or flocculation will be greatest at some intermediate water content. It has indeed been discovered experimentally (and before this theory was developed) that the physical properties of a soil which depend upon its degree of flocculation¹⁶ are at a maximum (or minimum) at a fairly definite water content intermediate between air-dryness and saturation. This water content has been called the "critical moisture content" and has been found, when allowance is made for biologic differences, to be practically identical with the optimum water content for the growth of ordinary plants. An increase of the water present above, or a decrease of it below, this critical content, decreases the susceptibility of the soil to flocculation and hence its capacity to be put in good tilth.

It is apparent from the above that in any particular soil there must be for each definite water content a corresponding structure or degree of aggregation which is normal for that water content. It does not follow, however, that the soil in the field always possesses the structure which is normal to it and for the water content which it happens at that moment to hold. Were the soil particles perfectly free to move among themselves, the soil mass would no doubt always possess the structure theoretically required by its water content, and changes in water content would be followed immediately by the corresponding changes in structure. But the soil particles are not free to move. Gravity (in the form of the weight of superposed soil), the adhesion of the grains, the friction between them, and similar factors, furnish an inertia which strongly resists any change of structure, especially the loosening which must accompany an increase in the degree of flocculation. In general, therefore, the actual structure of a soil at any particular moment is not that corresponding to its water content, but rather that which has resulted from the action of its various past water contents working against the inertial factors and complicated by various extraneous factors of which the main are the operations of agriculture.

¹⁶ The resistance to penetration, the apparent specific gravity, etc.

But although a soil does not in itself respond readily to changing water content, if it be artificially stirred, as *e.g.*, by plowing, the structure which it will take on is largely determined by its water content. Hence the importance of conducting cultural operations when the soil is neither too dry nor too wet—when, in scientific phrase, its water content is at or near the “critical” value. The existence of this “critical” (or optimum) water content in a soil does not mean necessarily that the soil possesses the optimum physical structure, but does mean that it has then and then only the capacity to take and retain that structure under the action of cultural processes.

The actual amount of water which corresponds to the maximum of flocculation (or better, capacity for flocculation) varies widely in different soil types. The values which have so far been obtained range from 30 to 40 per cent. (by weight) for clays to 3 and 4 per cent. for sands. Ordinary loams run from 10 to 20 per cent.

Though for most normal soils the surface tension forces as thus outlined are the strongest of those influencing flocculation, yet effects similar to those discussed in the first part of this paper are sometimes of importance, especially where the soil particles are very fine, as in clays. In these soils the interstitial spaces are so small as to be comparable in size with the minimum thickness of a water film capable of exerting mechanical forces. Consequently, when there is enough water present to provide surrounding films for all of the particles, the interstitial spaces are themselves nearly filled with water and the gas-liquid surfaces have largely disappeared. We approach here the case of suspension of solid particles in water and the laws of flocculation in such systems are fairly well applicable. The reactions, the so-called “colloidal clay,” the various phenomena of the baking, crusting, etc., of clay soils show many similarities to the phenomena of flocculation in suspensions, and it is probable that still more correspondences and analogies will appear as this field is more fully studied.

Though these phenomena (actions analogous to those of suspension-flocculation) are observable only in clays, it is probable that they are not confined thereto. There is indeed every reason to believe that they are duplicated in kind in all soils *at the liquid-solid surfaces*. In most soils, however, these effects are

entirely masked by the much stronger forces which act at the gas-liquid surface. Only when this surface is destroyed by saturation do the former effects become apparent.

All this concerns the action of water alone as an agent of soil flocculation. It remains to notice briefly the effects of substances dissolved in the water in modifying its flocculating action. The effects of such substances can manifestly be two-fold: (1) those on the flocculating forces at the liquid-solid surface; and (2) those on the gas-liquid surface tension of the water. It was long ago suggested that these effects, especially the second, are important items in the action of fertilizer salts on the soil, but there is an almost total lack of definite data, and accurate analysis of the phenomena is not possible at present. Practically, there are only two substances, the effects of which on soil flocculation are sufficiently clear and striking to have received general recognition: lime, which is a strong flocculator; and sodium carbonate ("black alkali") which has the opposite tendency. In neither of these cases is the mechanism of the action fully understood, but it is probable that both are in the main effects analogous to the phenomena occurring in suspensions, and concern only in minor degree the gas-liquid surface tension. This seems especially probable from the fact that these actions are very clearly shown by clays and hardly noticeable at all in sandy soils. We have already seen that the flocculation of soils of the former class is much more nearly analogous to that of suspensions.

BIBLIOGRAPHY.*

I. Suspension and Flocculation in General.

Barus, Carl.

The subsidence of fine solid particles in liquids. U. S. Geol. Surv., Bull. 36: (1886), 51 p.

The subsidence of fine solid particles in liquids. Amer. Jour. Sci. (3) 37: 122-129 (1889).

Barus, Carl, and Schneider, E. A.

Über die Natur der kolloidalen Lösungen. Zs. phys. Chem. 8: 278-297 (1891).

Bechhold, H.

Die Ausflockung von Suspensionen bzw. Kolloiden und die Bakterienagglutination. Zs. phys. Chem. 48: 385-423 (1904).

Billitzer, Jean.

Versuch einer Theorie der Mechanischen und colloidalen Suspensionen. Sitzungsber. Akad. Wiss., Wien., Abt. 2, 111: 1393-1432 (1902).

* This bibliography gives only a few of the more important titles. It makes no pretense of completeness.

- Zur Theorie der Suspensionen und der elektrischen Doppelschichte, Ib. 112: 1098-1106 (1903).
Eine Theorie der Kolloide und Suspensionen. Zs. phys. Chem. 45: 307-330 (1903).
- Bodlaender, G.**
Versuche über Suspensionen. Neues Jahrb. Min. 1893: II; 147-168.
- Brewer, William H.**
On the subsidence of particles in liquids. Mem. National Acad. Sci. 2: 163-175 (1884).
On the suspension and sedimentation of clays. Amer. Jour. Sci. (3) 29: 1-5 (1885).
- Durham, William.**
Suspension of clay in water. Chem. News 30: 57 (1874).
Suspensions of clay in water. Proc. Edinb. Phys. Soc. 4: 46-50 (1878).
Suspension, solution and chemical combination. Proc. Roy. Soc. Edinb. 9: 537-541 (1878), and Chem. News 37: 47-48 (1878).
- Ehrenberg, Paul.**
Die Beziehung der Kolloidforschung zur Agrikulturchemie. Zs. Chem. Ind. Kolloide 3: 193-206 (1908).
- Fickendey, E.**
Notiz über Schutzwirkung von Kolloiden auf Tonsuspensionen und natürliche Tonböden. Jour. Landw. 54: 343-348 (1906).
- Freundlich, Herbert.**
Über das Ausfällen kolloidaler Lösungen durch Elektrolyte. Zs. phys. Chem. 44: 129-160 (1903).
Kapillarchemie. Leipzig, 1909, 536 p.
- Hall, A. D., and Morison, C. G. T.**
The flocculation of turbid liquids by salts. Jour. Agric. Sci. 2: 244-256 (1907).
- Hardy, W. B.**
A preliminary investigation of the conditions which determine the stability of irreversible hydrosols. Proc. Roy. Soc. London 66: 110-125 (1899), and Zs. phys. Chem. 33: 385-400 (1900).
- Hermann, Hugo.**
Über das Absetzen von Tonemulsionen. Zs. anorg. Chem. 53: 413-418 (1907).
- Hilgard, E. W.**
On the flocculation of particles, and its physical and technical bearings. Amer. Jour. Sci. (3) 17: 205-214 (1879).
- Holland, P.**
See Reade, T. Mellard.
- Hunt, T. Sterry.**
The deposition of clays. Proc. Boston Soc. Nat. Hist. 16: 302-304 (1874).
- Joly, J.**
Preliminary note on the inner mechanism of sedimentation. Sci. Proc. Roy. Dublin Soc. (n. s.) 9: 325-332 (1900).
Some sedimentation experiments and theories. Sci. Trans. Roy. Dublin Soc. (2) 7: 391-402 (1902).
- Jordis, Eduard.**
Kritik der Grundlagen einer Theorie der Kolloide. Zs. Chem. Ind. Kolloide 2: 361-367; 3: 13-26, 153-166 (1908).
- Mayer, Adolf.**
Über die Einwirkung von Salzlösungen auf die Absetzungsverhältnisse thoniger Erden. Forsch. Geb. Agr.-Phys. 2: 251-273 (1879).
- Michaelis, Leonor, and Pinkussohn, Ludwig.**
Zur Theorie der Kolloidumhüllung. Biochem. Zs. 2: 251-263 (1906).
- Morison, C. G. T.**
See Hall, A. D.

Ostwald, Wolfgang.

Grundriss der Kolloidchemie. Dresden, 1909, 509 p.

Perrin, Jean.

Mécanisme de l'électrisation de contact et solutions colloïdales.

Jour. chim. phys. 2: 607-665 (1904); (3) 51-110 (1905).

Pinkusohn, Ludwig.

See Michaelis, Leonor.

Quincke, G.

Über die Bewegung und Anordnung kleiner Teilchen, welche in Flüssigkeiten schweben. Vehr. Ges. Naturf. und Aerzte 1898: 26-29.

Über die Klarung trüber Lösungen. Verh. Heidelb. naturh.-med.

Ver. (n. s.) 7: 97-104 (1901), and Ann. Phys. (Drude), (4) 7: 57-96 (1902).

The clearing of turbid solutions and the movement of small suspended particles by the influence of light. Report Brit. Assoc.

Adv. Sci. 1901: 60-64.

Ramsay, William.

On the influence of various substances in accelerating the precipitation of clay suspended in water. Quart. Jour. Geol. Soc. 32: 129-133 (1876).

Reade, T. Mellard, and Holland, P.

Sands and sediments. Proc. Liverpool Geol. Soc. 10: 48-78 (1905).

Reinders, G.

Beitrag zur Kenntniss der Einwirkung des Meerwassers auf den Boden. Landw. Versuchsstat. 19: 190-214 (1876).

Scheerer, Theodor.

Einige Beobachtungen über das Absetzen aufgeschwemmter pulverförmiger Körper. Ann. Phys. (Poggendorff), (2) 82: 419-429 (1851).

Schloesing, Ch.

Sur la précipitation des limons par des solutions salines très-étendues. Comptes rendus 70: 1345-1348 (1870).

Schneider, E. A.

See Barus, Carl.

Schulze, Franz.

Die Sedimentär-Erscheinungen und ihr Zusammenhang mit verwandten physikalischen Verhältnissen. Ann. Phys. (Poggendorff), (2) 129: 366-383 (1866).

Schulze, Hans.

Schwefelarsen in wässriger Lösung. Jour. prakt. Chem. (2) 25: 431-452 (1882).

Antimontrisulfid in wässriger Lösung. Ib. (2) 27: 320-332 (1883).

Skey, William.

Coagulation and precipitation of clay by neutral salts generally. Chem. News 17: 160 (1868).

Spring, W.

Sur la flocculation des milieux troubles. Bull. Acad. Roy. Belg., Classe de Sci., 1900: 483-520, and Rec. trav. chim. Pays-Bas. 19: 204-236 (1900).

Stuntz, Chauncey R.

Clarification of the public water supply of Cincinnati. Jour. Cin. Soc. Nat. Hist. 9: 20-35 (1886).

Waldie, D.

On the muddy water of the Hugli during the rainy season with reference to its purification and to the Calcutta water supply. Jour. Asiat. Soc. Bengal 42, II; 210-226 (1873).

Weimann, P. P. von.

Zur Lehre von den Zuständen der Materie. Zs. Chem. Ind. Kolloide 2: 199-208, 230-237, 275-284, 301-307, 326-335; 2: Suppl.-h.

II; LII-LXI; 3: 282-304; 4: 27-37, 123-139, 198-202, 252-265, 315-317;
5: 62-68, 117-120, 150-159, 212-221 (1907-9).

Zsigmondy, Richard.

Zur Erkenntnis der Kolloide. Jena, 1905, 185 p.

II. The Mechanics of Suspension.

Boggio, Tommaso.

Integrazione dell'equazione funzionale che regge la caduta di una sfera in un liquido viscoso. Rendiconti Accad. Lincei (5) 16, II: 613-620 (1907).

Buller, A. H. Reginald.

The rate of fall of fungus spores in air. Nature 80: 186-187 (1909).

Cunningham, E.

On the velocity of steady fall of spherical particles through fluid medium. Proc. Roy. Soc. London (A) 83: 357-365 (1910).

Orsi, Giovanni.

Über die Flugfähigkeit des Staubes. Arch. für Hygiene 68: 22-53 (1908).

Ostwald, Wolfgang.

Zur Theorie der Schwebevorgänge sowie der specifischen Gewichtsbestimmungen schwebender Organismen. Arch. gesammte Physiol. 94: 251-272 (1903).

Perrin, Jean.

La loi de Stokes et le mouvement brownien. Comptes rendus 147: 475-476 (1908).

Picciati, Giuseppe.

Sul moto di una sfera in un liquido viscoso. Rendiconti Accad. Lincei (5) 16, I: 943-951 (1907).

Integrazione dell'equazione funzionale che regge la caduta di una sfera in un liquido viscoso. Ib. (5) 16, II: 45-50 (1907).

Thoulet, J.

Expériences relatives a la vitesse des courants d'eau ou d'air susceptibles de maintenir en suspension des grains minéraux. Ann. de Mines, Mémoires, (8) 5: 507-530 (1884).

De l'influence du vent dans le remplissage du lit de l'océan. Comptes rendus 146: 1184-1186 (1908).

Uller, K.

Über den Verdrängungswiderstand fester Körper in Gasen und Flüssigkeiten. Ann. Phys. (Drude) 23: 179-196 (1907).

Zeleny, John, and McKeehan, L. W.

An experimental determination of the terminal velocity of fall of small spheres in air. Science (n. s.) 29: 469 (1909).

The terminal velocity of fall of small spheres in air. Nature 82: 158 (1909).

Bureau of Soils,
U. S. Department of Agriculture,
Washington, D. C.

THE HOPKINS GASOLENE-ENGINE DYNAMOMETER AND SPEEDOMETER.

BY

N. MONROE HOPKINS, Ph.D.,

WASHINGTON, D. C.

(Stated Meeting held Wednesday, January 19, 1910.)

[It is not ordinarily a simple operation to determine the power continuously delivered by an internal combustion engine. The apparatus here described is designed to reduce the operation to the simplicity of reading the horsepower from a dial and essentially consists of a current meter whose readings are proportional to the product of the speed of rotation and the temperature of the gases within the cylinder.]

THE following is a brief description of the experimental work undertaken at the laboratory of the writer in developing a dynamometer for indicating the working conditions existing in the cylinders of gas and gasoline motors. It occurred to the author of this paper that a thermocouple as evolved by Becquerel for measuring temperatures as existing in the various types of commercial furnaces for steel, porcelain, etc., would cast much light on certain important conditions which exist within the cylinders of internal combustion motors. A sensitive thermocouple, it was evident, would show temperature, indicate immediately the failure of any cylinder to fire in the case of multiple cylinder motors, and more important, such a thermocouple would show carburetor adjustment. It is well known that the highest temperature in an engine cylinder is attained when just enough hydrocarbon vapor is drawn into the cylinder with just enough air, the oxygen from which completely converts the hydrocarbon vapor into its ultimate combustion products.

Not possessing a suitable automobile engine at the time of carrying out the initial experiments, one was borrowed for making the test and four improvised plugs carrying simple Becquerel thermocouples were constructed by the writer, in his Washington laboratory, and were connected to a specially designed milli-voltmeter attached to the dash of an automobile. Fortunately or unfortunately, the automobile belonged to a friend! On first cranking the motor the engine started off beautifully and an indication was at once shown upon the electrical

instrument, but the smooth and perfect operation of the motor was only momentary—violent pounding and bucking being soon apparent. In attempting to drive the car up the street, the engine was nearly shaken to pieces because of violent pre-ignition, discovered to be due to the hot thermocouple protruding into the

FIG. 1.

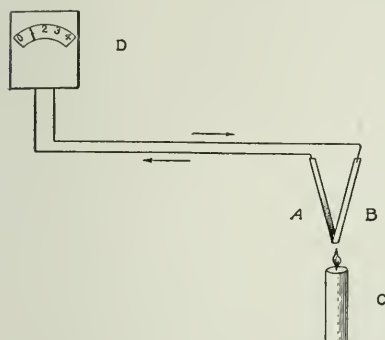
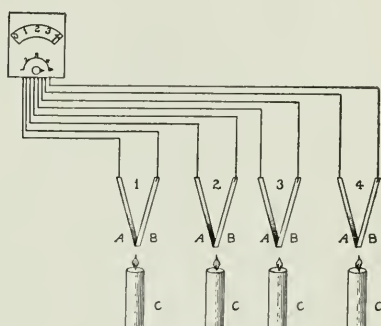


FIG. 2.



cylinders. Since that time, constant experimental work has been in progress with the view of developing a thermocouple of successful operation within gasolene-engine cylinders.

Fig. 1 shows the fundamental principle as evolved by Becquerel, illustrated by the candle flame, thermocouple and voltmeter.

TABLE I.

GAS MIXTURE	GAUGE PRESSURE	TEMPERATURE, F.
1 gas to 13 air	52	1,916 degrees
1 gas to 11 air	63	2,309 degrees
1 gas to 9 air	69	2,522 degrees
1 gas to 7 air	89	3,236 degrees
1 gas to 5 air	96	3,484 degrees
1 gas to 4 air	80	2,111 degrees

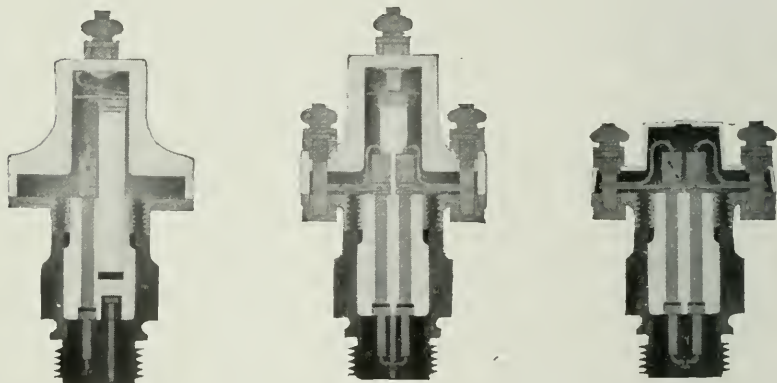
Fig. 2 shows an elaboration of Becquerel's pyrometer—applied with disastrous effects to a four-cylinder automobile! Table I shows in column one gas mixture, gauge pressure in column two, and temperature in column three. It is evident from study of this table that a thermocouple, if it could be made to operate successfully in the several cylinders of a cylinder motor, would prove of inestimable value in showing best gas mixture or carburetor adjustment and it will be noted that when a mixture of 1 gas to 5 air is admitted the maximum gauge pressure,

namely 96 pounds, is attained, also the maximum temperature of 3484 degrees.

As pointed out, ordinary thermocouples as evolved by Becquerel, shown in the foregoing diagrams and used for general temperature measurement in the arts and sciences, would never "live" or operate under the peculiar chemical conditions in a gasolene-engine cylinder. Not only because they would become so heated as to pre-ignite the charge and cause the engine to buck, hitch or back-fire, as already described, but in addition would become brittle and drop apart through either oxidation or the absorption of carbon after a short period of use.

Actual temperature measurements by means of thermo-

FIG 3.

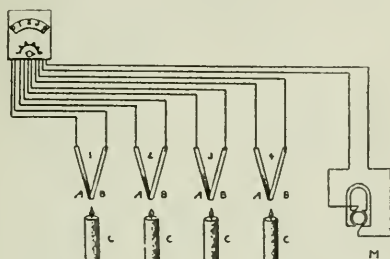


couples or thermometers of any kind could not be made in gasolene-engine cylinders. As a result of the experimental work conducted it has been made possible, by means of especially designed and constructed thermocouples, the limbs of which are enveloped in massive metal tubes, to give an *index* of the temperature in a gasolene-engine cylinder without attempting actually to measure it.

The dynamometer as finally constructed faithfully and continuously shows by these modified temperature readings the working conditions of gasolene-engine cylinders. Fig 3 shows the cross-section of some of the special thermocouples enveloped by heavy metal tubes, insulated by porcelain bushing, and made gas-tight within a steel-threaded shell for screwing into an engine cylinder. Such thermocouples made from even base metals and

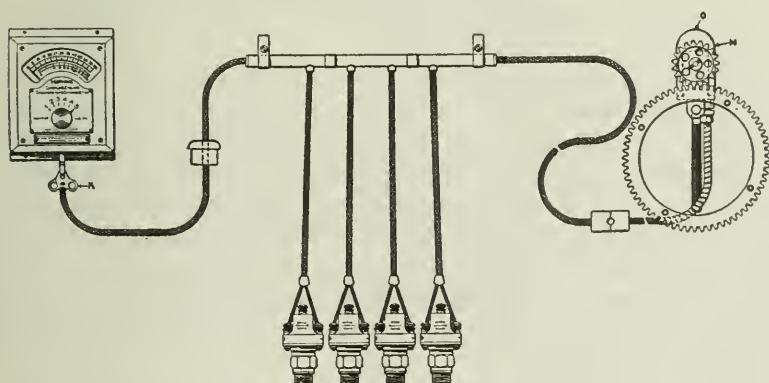
protected by metal tubes (providing an adequate thermal circuit is formed) will indicate for practically an unlimited period of time without pre-ignition or back-fire and without undergoing molecular changes, oxidation or reduction.

FIG. 4.



By using specially constructed spark plugs carrying thermocouple wires with a heat conducting tube around each limb of the thermocouple, the heat from the tip of the same is carried away at a predetermined rate. All thermocouples may be easily calibrated to read alike by carefully adjusting their lengths which protrude beyond the end of the copper tube. They are then

FIG. 5.

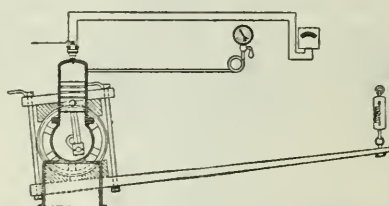


soldered in the oxyhydrogen blow-pipe flame when all the thermocouples become interchangeable and give the same electromotive force.

An exceedingly sensitive, satisfactory and practical instrument has been constructed upon this principle, that is, of making a thermocouple by virtue of its construction and production, to

maintain itself below the point of pre-ignition in a gas or gasoline-engine cylinder. In Fig. 2 it will be observed that the electrical indicator is provided with a switch by the turning of which it may be connected *selectively* to thermocouple No. 1, No. 2, No. 3, or No. 4, enabling one to determine if the four temperatures are of even intensity. Each separate thermocouple, for example, will give a reading of 1, if now we provide the switch with an additional contact "A" (all) the four thermocouples may be connected in *series* and the intensity of all the temperatures be indicated *collectively* upon the scale when the reading will be 4. Six thermocouples connected would cause the instrument to indicate 6 scale divisions and so on up to any number desired. Any variation in the temperature of the metallic junction becomes apparent upon the electrical indicator. When the switch is on the "A" contact and all the thermocouples are connected in series, it is

FIG. 6.



evident that the instrument serves as a refined method for a sensitive adjustment of the carburetor for maximum engine efficiency. In addition to this feature, by providing an additional circuit going to a small magnetodynamo the electrical indicator is made to serve as a precision indicator of speed—miles per hour for motor vehicles or revolutions per minute for motor boats and aeroplanes and for any revolving piece of machinery. This dynamo, when suitably constructed, furnishes direct current to the electrical indicator in direct proportion to the speed at which the dynamo is driven.

Fig. 4 will make this clear. Here we have four thermocouples as shown before but with the additional circuit at the right of the diagram connected with the small magnetodynamo "M" and the additional switch contact marked "S" (speed) on the face of the electrical indicator. If the magnetodynamo is now geared to the left front wheel of an automobile or the shaft of a motor boat or aeroplane, the indicating instrument may be

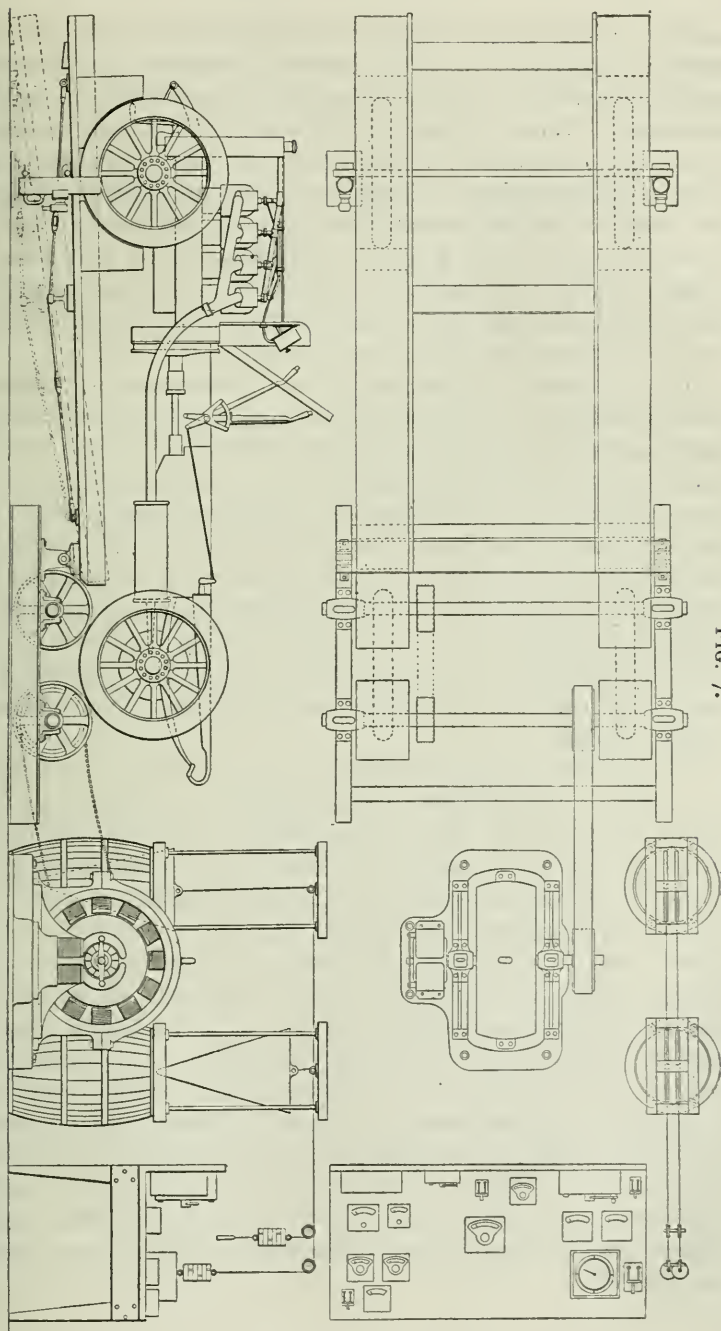


FIG. 7.

DESIGNED BY
N. H. O'PAIN.
JAN. 12, 1908
Pat. 817,141.

made to read miles per hour, or revolutions per minute when the switch is turned on "S." The electrical indicator thus becomes a precision indicator of speed, operating independently of the thermocouples. When the switch is turned to "A" the indicating instrument becomes a power indicator and operates independently of the magnetodynamo. Should a cylinder miss firing the faulty one may be located instantly by turning the switch over the numerals, 1, 2, 3, and 4, the needle falling off to zero when the "dead" cylinder is reached. The switch is so constructed that the electrical indicator cannot be connected to the magnetodynamo and to the thermocouples at the same time.

Fig. 5 shows a dynamometer and speedometer complete as finally developed. Here we have the magnetodynamo driven by a large gear-wheel for application to an automobile, a brass armored rubber-covered cable being substituted for all separate wires. In the centre are the four specially constructed spark plugs suspended from a distributor bar and at the left the indicating instrument with the switch, all united in a compact system through the agency of a rubber-covered cable protected by flexible brass armor duct. The key "K" shown under the instrument at the left is for precise calibration of the instrument for speed by turning in or turning out resistance in the magnetodynamo circuit.

Fig. 6 shows diagrammatically a pressure gauge and one of the writer's dynamometers both applied to an engine equipped with a Prony brake. The dynamometer, to a surprising degree, shows the pressure in the same manner as the mechanical gauge.

Fig. 7 shows an automobile chassis mounted upon a rolling type of dynamometer for calibrating the lower scale of the writer's electrical indicator by means of wattmeters, an alternating current generator and water rheostat. When all four thermocouples are connected in series, "A" contact, the electrical indicator behaves as a true power indicator. A temperature of compression in addition to the temperature of combustion causes the index of the instrument to follow the index of the wattmeter when under load and mounted upon such a testing equipment as shown in the last figure. Experiments with this indicator and its performance in engineering practice have secured the deepest interest, and technically have surpassed the writer's most hopeful expectations.



HARRY WALKER JAYNE, PH.D.

IN MEMORIAM.

Harry Walker Jayne, Ph.D.

By the death of Dr. Harry Walker Jayne at his home in Elkins Park on Monday, March 7th, 1910, in the fifty-third year of his age, a prominent place was made vacant, both among the leading members of the Franklin Institute and in the foremost rank of chemists in America. A close student of the chemistry of the coal-tar products, Dr. Jayne combined with the temperament of a genial personality the qualities of an accomplished technologist, a lucid writer and lecturer and of a practical and successful business man. His contributions to the literature of his specialty, published in the Proceedings of various scientific assemblies at home and abroad, in the JOURNAL OF THE FRANKLIN INSTITUTE and in other scientific periodicals, gained for him a recognized place as an authority on the technology of coal-tar and its innumerable products. Especially notable among Dr. Jayne's writings is his paper on "The Coal-Tar Industry in the United States" published in the Report of the Fifth International Congress of Applied Chemistry, Berlin, 1904, and that on "Determination of Water in Tar" in the *Journal of American Chemical Society*, vol. xiv, 1903. His library of chemical literature is reputed as among the most extensive private collections of this kind on either side of the Atlantic and embraces publications in all modern languages.

Dr. Jayne was born in Philadelphia June 16, 1857, son of the late David W. and Ellen F. Jayne, and grandson of Dr. David Jayne, the originator of the proprietary medicine known by his name. His education was begun in private schools in this city and was continued in the University of Pennsylvania, where he entered as a special student in the Junior Class in 1873 and remained until June, 1875. He then proceeded to Europe, where he spent a year at the University of Heidelberg, two years in Paris at the Sorbonne and the École de Médecine and two years at the University of Strasburg, obtaining from the last named institution the degree of Ph.D. in 1883. Returning home in that year, he soon thereafter established himself in the Frankfort district of Philadelphia as a manufacturer of fine chemicals and ultimately developed the business in the direction of the coal-tar products. In this specialty, the undertaking grew to large proportions and in 1896 was taken over by the Barrett Mfg. Co., of which concern Dr. Jayne continued as the managing director. He was a trustee of the estate of his noted grandfather and a co-manager with his brother, Mr. H. LaBarre Jayne, of the business of Dr. D. Jayne & Son. He is survived by his widow, born Florence N. Adams, of this city, and by three sons, David W., Chas. A., and Harry W. Jayne, Jr.

Besides his active connection with the Franklin Institute, Dr. Jayne was a member of the American Institute of Chemical Engineers, the American Chemical Society, the English Society of Chemical Industries, the Société Chimique of Paris, the Deutsche Chemische Gesellschaft, Berlin, the En-

gineers' Club of Philadelphia, and the Geographical Society of Philadelphia.

Dr. Jayne's membership of the Franklin Institute dates from September, 1874, when he was still a minor, and continued until his untimely death. In 1891 he was elected a member of the Board of Managers of the Institute and collaborated in that capacity with all the zest of his earnest nature. In May, 1903, he was appointed Chairman of the Committee on Publications in succession to the late Theodore D. Rand, and notwithstanding that his health became impaired as much as five years ago and gradually gave way increasingly, he continued his activity in that position until within barely over a year ago, when his failing strength prevented him from longer giving it his customary close attention.

Dr. Jayne was a notable example of devotion to duty and of efficiency in its performance, a man who fulfilled with precision and in detail whatever task was undertaken by him. Though his years fell all too short of the allotted span, they bore all the fruitage of a life well spent in study, service and accomplishment.

LOUIS EDWARD LEVY.

BOOK NOTICES.

PENROSE'S PICTORIAL ANNUAL. The Process Year Book. Edited by William Gamble. Volume xv, 1909-10. New York, Tennant and Ward. Contains 200 pages, illustrations, plates, 8vo. Price in cloth, \$2.50.

The current issue of this well-known annual contains the usual amount of interesting information for the process worker. Sixty-nine articles, by contributors from all parts of the world, comprise the reading matter, numerous full-page specimens of two-, three-, four- and five-color prints are shown, and innumerable half-tones are distributed throughout the text. A photograph serves as frontispiece and one specimen of steel-plate engraving is included. The presswork is done with the usual care and the binding is uniform with previous volumes. R.

DER GRAPHIT. Eine technische Monographie von Ingenieur A. Haenig. 224 pages, illustrations, 12mo. Wien & Leipzig, A. Hartleben, 1910. Chemisch-technische Bibliothek, Band 323. Price, in paper, four marks.

As the literature on the subject of graphite is somewhat limited, those who are interested will undoubtedly find the present work useful. It contains in its 200 odd pages a review of the history of graphite; its properties and formation and the origin of the graphite deposits. Extraction, preparation and purification are followed by several chapters on its applications. The manufacture of lead-pencils is described and considerable attention is given to crucible making. The statistics of the subject are not overlooked, eleven pages being devoted to the world's production. The work closes with a chapter on artificial graphite. R.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, June 15, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1910.

President WALTON CLARK *in the Chair.*

Present, 211 members and visitors.

Additions to membership since last report, 5.

The subject of the evening was presented by Mr. F. H. Stewart assisted by Mr. Max Milligan, the former gentleman presenting a brief outline of the history and development of picture projection. The most recent type of moving picture machine as made by the Edison Manufacturing Company was shown, and Mr. Milligan described the various films as they were projected on the screen. At the close of the demonstration a vote of thanks was tendered to the speakers and on the motion of Mr. Levy the subject was referred to the Committee on Science and the Arts for consideration. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS

(Proceedings of the Stated Meeting, held Wednesday, June 1, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 1, 1910.

Mr. THOMAS SPENCER in the Chair.

The following report was presented for final action:

(No. 2463.) Murray's Safety Devices and Protective Appliances for Interior Electric Lighting. (Adopted, Longstreth Award.)

For first reading:

(No. 2421.) Wetherill's Instruments to Aid Navigation. (Advisory, Adopted.)

(No. 2481.) The Moore Light.

(No. 2491.) Deloe's Door Controller. (Advisory, Adopted.)

(No. 2496.) Branch's Asbesto Gleam Shades.

R. B. OWENS,
Secretary.

SECTIONS

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening April 21 at eight o'clock; present, eighty members and visitors. In the absence of the Chairman, Dr. E. Goldsmith opened the meeting. After reading of the minutes the Chairman introduced Mr. Lennart Akesson, Director of the Swiss Liquid Gas Works, Zurich, who presented a communication on Liquid Gas, its manufacture and uses. The speaker described the process of Liquid Gas manufacture invented by Linus Wolf, and illustrated the subject by means of lantern slides and portable gas apparatus. After a brief discussion, which followed the paper, a vote of thanks was tendered the speaker for his interesting communication and the invention was referred to the Committee on Science and the Arts for investigation and report. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Electrical Section.—A meeting of the Section was held on Thursday evening, April 28, 1910, at eight o'clock; present, sixty-five members and visitors. The meeting was called to order by Mr. Thomas Spencer, Chairman of the Section. After the reading of the minutes the chairman introduced Dr. Morton G. Lloyd, Associate Physicist of the Bureau of Standards, Washington, D. C., who spoke on Magnetic Hysteresis. The speaker described the latest methods of measuring magnetic quality in general and in particular the losses which occur in iron and iron alloys when placed in alternating and rotary magnetic fields. The results clearly showed the great improvement made in recent years in the quality of magnetic material used by the manufacturer of electrical apparatus of to-day. The subject was illustrated by lantern slides and specimens of metals. A brief discussion followed in which Dr. E. F. Northrup, Prof. Carl Hering, Dr. R. B. Owens, Dr. Goldsmith, the Speaker and the Chairman participated.

The thanks of the meeting were extended to Dr. Lloyd for his interesting address and his paper was referred to the Committee on Publications. Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section on Physics and Chemistry.—The stated meeting of the Section held in the Hall of the Institute on Thursday, May 5, 1910, at 8 P.M. with Dr. Goldsmith in the Chair; present, thirty-five members and visitors. The minutes of the previous meeting were read and approved.

Mr. James Wood Pogue, Treasurer of the United States Linen Flax Corporation, presented a communication upon "Flax Growing and Linen Manufacturing in the United States, Present and Future." With the aid

of lantern slides, the time consuming mode of preparation of linen fibre as practised in the Old World for four thousand years, was described. An account was given of the Roberts process for the manufacture of linen fibre from flax, which is based upon the following treatment: (1) Mechanical breaking or shredding of flax straw; (2) boiling the shredded fibre in an alkali bath; (3) washing with water; (4) treatment in an acid bath; (5) washing with water; (6) treatment in a soap bath; (7) washing with water. The fibre then is combed and spun in the usual way. In conclusion it was stated that linen manufacture may be carried out in the United States on a large scale. The communication was discussed.

The thanks of the meeting were tendered Mr. Pogue; the paper was referred to the committee on Publications and the invention to the Committee on Science and the Arts. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—The stated meeting of the Section on Thursday evening May 12, at eight o'clock, with Dr. Robert H. Bradbury, president of the Section, in the Chair; present, forty-five members and visitors.

Joseph S. Hepburn, A.M., M.S., Secretary of the Section, delivered an address upon "Recent Progress in the Chemistry of the Sugars." The nomenclature of the sugars was explained and the reactions involved in Fischer's syntheses of monoses, glucosides and disaccharides were discussed. The behavior of the synthetic sugars toward yeasts, and the action of the inverting enzymes,—invertin, emulsin, maltase and lactase,—upon the glucosides and disaccharides were considered. Mention was made of the modes of separation of racemic compounds of the sugar group into their antipodes, and attention was given to the asymmetric syntheses which occur within that group. The lecture was illustrated with lantern slides, and with specimens of the sugars and their related compounds.

The paper was referred for publication. On motion of Dr. Harry F. Keller, a vote of thanks was tendered the speaker. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

At the Stated Meeting of the Board of Managers, held Wednesday, June 8, the following gentlemen were elected to membership:

Resident.

JOSEPH REED COLLINGWOOD, 511 South Forty-first St., Philadelphia, Pa.

MATTHEW H. DEVEY, 2443 North Twenty-ninth St., Philadelphia, Pa.

Non-Resident.

FRANK HEPBURN, 157 West Forty-fourth St., New York City.

S. J. MACFARREN, 1403 New York Ave., Washington, D. C.

OSWALD WEIGEL, Königstrasse 1, Leipzig, Germany.

Change of Address.

CHARLES E. FOSTER, 908 G St., N. W., Washington, D. C.

ROBERT JOB, care Milton Hersey Company, Ltd., 171 St. James St., Montreal, Canada.

H. PEMBERTON, JR., Adirondack Summer School, Saranac Lake, N. Y.

F. RODNEY PLEASANTON, 108 North Second St., Harrisburg, Pa.

OBITUARY.

C. J. Toerring died in Philadelphia, Pa., April 22. He was born in Skive, Denmark, September 18, 1870. After completing the public school course in Davenport, Iowa, he entered the University of Illinois at Urbana, transferring to Cornell University in his junior year and graduated in 1893.

For about a year he was engaged in the laboratory and engineering department of an arc lamp company in New York City, and later became associated with the Helios Electric Company, of Philadelphia.

In 1898 he organized the company which bears his name.

The arc lamps of his design are considered of distinctive merit. They were granted recognition at numerous expositions, including the gold medal at the Paris Exposition in 1900; highest award at the National Export Exposition, Philadelphia, 1899; also awards at Buffalo, N. Y., in 1901, and St. Louis in 1904. The Edward Longstreth medal of merit was awarded by the Franklin Institute in 1903. He was a strong advocate of inverted lighting, *i.e.*, indirect illumination, and his inverted enclosed arc lamp, which he designed some years ago, gained many converts to this method of lighting.

LIBRARY NOTES.

Purchases.

- ARMSTRONG, E. F.—"Simple Carbohydrates and the Glucosides."
Century Dictionary and Cyclopædia, vols. 11-12, 1909 edition.
- CUSHMAN, A. S., and H. A. GARDNER.—"Corosion and Preservation of Iron and Steel."
- GODFREY, EDWARD.—"Concrete."
- GODFREY, EDWARD.—"Godfrey's Tables."
- HUBBARD, PRÉVOST.—"Dust Preventives and Road Binders."
- JONES, H. C.—"Elements of Physical Chemistry," Ed. 4.
- LAMB, HORACE.—"Dynamical Theory of Sound."
- Marseille Congrès International des Application de Electricite, 3 vols.
"Meteorologischen Zeitschrift Namen und Sachregister," Bänden 1, xxv, 1884-1908.
- RICHARDS, ROBERT H.—"Ore Dressing," vols. iii and iv and Index.
- SCHAFFERS, V.—"Machine a Influence son Evolution, sa Theory."
- STEINMETZ, C. P.—"General Lectures on Electrical Engineering."
- STEINMETZ, C. P.—"Theory and Calculation of Transient Electric Phenomena and Oscillations."
- STEWART, A. W.—"Recent Advances in Physical and Inorganic Chemistry."
- WEINGREEN, J.—"Electric Power Plant Engineering."
- WILSON, H. M.—"Irrigation Engineering," Ed. 6.

Gifts.

- Inspector's Handbook of Reinforced Concrete, by Ballinger and Perrot.
Ontario Bureau of Industries, Report, Toronto, 1909.
- Ontario Agricultural College, Report, Toronto, 1910.
- Society of Naval Architects and Marine Engineers, Transactions, vol. 17
Washington (n.d.).
- Connecticut Geological and Natural History Survey, vol. 2, Hartford, 1909.
- "The Theory of Electrons," by H. A. Lorentz, New York, 1909.
- Report on the Blackwell's Island Bridge, Pennsylvania Steel Co., Steelton, 1909.
- Springfield, Mass., Water Commissioners, Report, 1909.
- Nova Scotia Mines Department, Report, Halifax, 1910.
- Newton, Mass., City Engineer, Report, 1909.
- Hebrew Technical Institute, Report, 1909; Catalogue, 1910, New York (n.d.).
- Georgia Geological Survey, Bulletin No. 23, Atlanta, 1910.
- "Fields of Force," by Vilhelm Friman Koren Bjerknes, New York, 1906.
- Philadelphia Board of Directors of City Trusts, Report, Philadelphia, 1910.

TRADE CATALOGUES.

- American Car and Foundry Company, Catalogue B, New York, 1903; Catalogue D, New York (n.d.).
- "How to Light Your Home by Electricity," The Electric Storage Battery Co., Philadelphia.

PUBLICATIONS RECEIVED.

The Standard Oil Company. By Elbert Hubbard, being a reprint from *The Fra* (Magazine). 24 pages, 12mo. East Aurora, N. Y. The Roycrofters 1910.

Das C. R. Gesetz und die Kabelschneeltelegraphie von Béla Gáti. Sonderabdruck aus "Electrotechnik und Maschinenbau," Zeitschrift des Elektrotechnischen Vereins. In Wien, Heft 37, 1909. 5 pages, illustrations, 4to. Vienna. n. d.

U. S. Department of the Interior. The Bureau of Science, Manila. The Mineral Resources of the Philippine Islands with a Statement of the Production of Commercial Mineral Products during the year 1908. Issued by Warren D. Smith, Ph.D., Chief of the Division of Geology and Mines, Bureau of Science. 49 pages, illustrations, plates, maps, 8vo. Manila, Bureau of Printing, 1909.

Canada Department of Mines. The Production of Asbestos in Canada during the calendar year 1907-8. By John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 8 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin. Bericht über die Tätigkeit des Amtes im Betriebsjahr 1908 (April, 1908, bis April, 1909). Sonderabdruck aus Mitteilungen aus dem Königlichen Materialprüfungsamt zu Gross-Lichterfelde West. 87 pages, 4to. Berlin, Julius Springer, n. d.

Le Revers de la Révolution. L'Insurrection en Russie, armée aux frais du Japon. 19 pages, 8vo. St. Petersburg, "Golos Pravdy," 1909.

Canada Department of Mines. The Production of Chromite in Canada during the Calendar Years 1907-8. By John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. 6 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

International Institute of Agriculture at Rome. Letter written by David Lubin to Hon. George C. Perkins and Hon. Frank P. Flint relative to the International Institute of Agriculture at Rome. Read in the U. S. Senate by Mr. Perkins. 6 pages, 8vo. Washington, 1909.

Recherches sur la préparation électrolytique des composés du plomb. Par Carl Duvivier. 19 pages, 8vo. Malines, L. and A. Godenne, 1909.

La Définition et la Mesure industrielles de l'Accélération des Trains. Par C. O. Mailloux, avec notes de R. Legouëz et J. Blondin. Extraits de la Revue électrique du 30 Novembre et du 30 Décembre 1908. 11 pages, 4to. Paris, Gauthier-Villars, 1908.

Report of a Fire-, Load- and Water-Test made upon Reinforced-Cinder-Concrete Floor-Arches constructed by the Trussed Concrete Steel Company at the University Fire-Testing Station, New York City, Test conducted by Ira H. Woolson, E.M., Adjunct Professor of Civil Engineering, in co-operation with the City Building Bureaus. 28 pages, illustrations, 8vo. Paper, price 25 cents. New York, 1909.

Canada Department of Mines. Report on the Iron Ore Deposits Along the Ottawa (Quebec side) and Gatineau Rivers, by Fritz Cirkel. 147 pages, illustrations, plates, maps, 8vo. Ottawa, Government Printing Bureau, 1909.

Against the Capital of K. Marx the Theory of the Technical Rents, by Engineer A. Trofimoff (in Russian). 292 pages, plates, 8vo. Tula, Russia, 1910.

Metal Industry Directory 1910. 8 pages, 8vo. New York, Metal Industry Publishing Co. (n.d.).

U. S. Coast and Geodetic Survey. Results of Magnetic Observations Made by the Coast and Geodetic Survey Between July 1, 1908, and June 30, 1909, by R. L. Faris, Inspector of Magnetic Work. Appendix No. 3. Report for 1909. 77-149 pages, 4to. Washington, Government Printing Office, 1910.

U. S. Coast and Geodetic Survey. Distribution of the Magnetic Declination in Alaska and Adjacent Regions, for 1910, by R. L. Faris, Inspector of Magnetic Work. Appendix No. 4. Report for 1909. 151-179 pages, maps, 4to. Washington, Government Printing Office, 1910.

U. S. Geological Survey. Mineral Products of the United States, Calendar years 1899 to 1908. Edward W. Parker, Statistician in charge of Mineral Resources. Sheet 24 x 32 inches. Washington, 1909.

Oxhydic Process for the Cutting and Welding of Metals. 23 pages, illustrations, 8vo. Milwaukee, American Oxhydic Co., January, 1910.

Canada Department of Mines. Production of Natural Gas and Petroleum in Canada During the Calendar Years 1907 and 1908. 15 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Canada. Department of Mines. The Production of Coal, Coke, and Peat in Canada During the Calendar Years 1907 and 1908. 34 pages, 8vo. Ottawa, Government Printing Bureau, 1909.

Canada. Department of Mines. The Production of Iron and Steel in Canada During the Calendar Years 1907 and 1908, by John McLeish, B.A., Chief of the Division of Mineral Resources and Statistics. Ottawa, Government Printing Bureau, 1909.

U. S. Bureau of Steam Engineering. Annual Report of the Chief of the Bureau to the Secretary of the Navy, for the Fiscal Year 1909. 70 pages, 8vo. Washington, Government Printing Office, 1909.

The Truth About Mexico, by E. S. Smith. 8 pages, portrait, 8vo. Reprinted from the Bankers' Magazine, November, 1909.

Industrial Peace and Industrial Efficiency. Sir Christopher Furness's Co-partnership Scheme. An account of "The Treaty of the Hartlepoons." 30 pages, 8vo. New York, American Anti-Boycott Association (n.d.).

Royal Institution of Great Britain. Tantalum and its Industrial Applications, by Alexander Siemens. 8 pages, 8vo.

————— The World of Life: as Visualized and Interpreted by Darwinism, by Alfred Russel Wallace. 7 pages, 8vo.

————— The Electrical Properties of Flame, by Prof. Harold Albert Wilson. 4 pages, 8vo.

————— Experiments at High Temperatures and Pressures, by Richard Threfall. 20 pages, illustrations, 8vo.

————— Solar Vortices and Magnetic Fields, by Prof. George E. Hale. 16 pages, plates, 8vo.

————— Researches in Radiotelegraphy, by Prof. J. A. Fleming. 32 pages, 8vo. London, Institution, 1909.

U. S. Department of Agriculture. Forest Service Circular No. 171: "The Forests of the United States—Their Use," by Overton W. Price, Associate Forester, and R. S. Kellogg and W. T. Cox, Assistant Forester. 25 pages, 8vo. Forest Service Circular No. 172: "Method of Increasing Forest Productivity," by E. E. Carter, Assistant Forester. 16 pages, 8vo. Washington, Government Printing Office, 1909.

Biographical Sketch of L. A. Bauer, reprinted from The National Cyclopædia of American Biography. 8 pages, portrait, 16mo. New York, James T. White & Co., 1909.

Recent Observations in Atmospheric Electricity, by P. H. Dike. 197-209 pages, 8vo. Reprinted from the American Journal of Science, vol. xxvii, March, 1909.

Carnegie Institution, Department of Terrestrial Magnetism. Annual Report of the Director, 1909. 194-202 pages, plates, 8vo. Reprinted from Year-Book No. 8.

An Experimental Investigation of Dip-needle Corrections, by P. H. Dike. 137-146 pages, illustrations, 8vo. Reprinted from Terrestrial Magnetism and Atmospheric Electricity for September, 1909.

United States Magnetic Tables and Magnetic Charts for 1905, by L. A. Bauer. 41-53 pages, 8vo. Reprinted from Terrestrial Magnetism and Atmospheric Electricity for March, 1909.

Zoölogical Bulletin of the Division of Zoölogy of the Pennsylvania Department of Agriculture. Vol. vii, Nos. 3 to 10, 8 pamphlets, 8vo. H. A. Surface, M.S., Economic Zoölogist, Editor. Harrisburg, State Printer, August, 1909, to March, 1910.

Manchester Steam Users Association. Memorandum by Chief Engineer for the Year 1908. 65 pages, illustrations, 8vo. Manchester, Taylor, Garnett, Evans & Co., 1909.

The Periodic Law and the Hydrogen Spectrum. By W. F. Kemble and C. R. Underhill. 16 pages, plates, 8vo. New York, D. Van Nostrand Co., 1909. Paper, price 50 cents.

CURRENT TOPICS

Vibrations of an Incandescent Filament. (*Sci. Americ.*, xii, 17.)—By microphotographic methods, the vibrations in an incandescent filament, due to the expansion and contraction caused by the passage of an alternate current, have been recorded. An arc lamp was used as the source of light for photographic purposes, and when the arc was fed from the same alternator as the incandescent filament, the vibrations were seen from the plate to synchronize with the rise and fall of the alternating pressure. With a 100 candle-power osram lamp, supplied with alternate current at 50 alternations, a slight humming noise was perceptible even at a distance of three yards. The experimenter considers that this may be a cause contributing to the shorter life of a metallic filament on alternate current.

Drawn Tungsten Filaments. (*Sci. Americ.*, xii, 17.)—Tungsten filaments are commonly made by mixing the metal in a paste that is then extruded in the form of a filament, after which the paste is expelled and the particles of metal are welded together by an electric current. This complicated method of forming the filaments is due to the fact that tungsten is not sufficiently ductile to be drawn out into fine filaments. An English concern has just discovered a method of producing drawn filaments of tungsten, and the General Electric Company has also just announced the discovery of a method by which tungsten may be rendered sufficiently ductile to permit of its being drawn into fine wires. The drawn tungsten filament is stronger than the filament made by the "sintering" process.

Synthetic Rubber. (*Sci. Americ.*, xii, 17.)—Prof. KARL HARRIES, of the University of Kiel, is said to have produced a synthetic rubber. The actual details of the process are not yet available. Similar attempts have been made repeatedly, but with no commercial success. The most that can be said for them is that they indicate the possibility of producing a synthetic rubber from turpentine at some future time.

Synthesis of Methane. BONE and COWARD. (*La Nature*, No. 1925.)—Messrs. Bone and Coward have studied the conditions of the direct combination of carbon and hydrogen and have realized the synthesis of methane. They state they have formed large quantities of this gas when less than 0.1 Gm. of the carbon from sugar was heated in a current of pure and dry hydrogen between 1100° and

1200° C., in an apparatus specially constructed to attain these temperatures. The carbon used was purified by prolonged heating in dry chlorine at a temperature from 700° to 1100° C. In two different experiments, they obtained 137 c.c. and 125.5 c.c. of methane, measured at 0°, and 760 mg., from 0.095 Gm. and 0.092 Gm. of carbon respectively, which is a yield of about 73 per cent. of the theoretical proportion; the rest of the methane was lost either through oxidation or by a decomposition, unavoidable on account of the intense heat of the walls of the porcelain tube in which the carbon was heated. The observers have thus convincingly confirmed the synthesis of methane from its elements, carbon and hydrogen, a synthesis which has often been disputed, and which in any case has only been successful with very small quantities of the substances.

Sterilization of Water by the Ultra-Violet Rays. (*La Nature*, No. 1925.)—Messrs. V. HENRY, A. HELBRONNER, and CH. VON RECKLINGHAUSEN have designed an apparatus which practically realizes the sterilization of running water by means of the ultra-violet rays. This apparatus sterilizes 125 cubic metres per hour, which is sufficient to supply a town of 20,000 inhabitants. The cost of the electricity required to effect the sterilization is 36 watts per hour per cubic metre. The apparatus has been tested by water previously contaminated with various microbes. The proof was quite decisive as the sterilization was complete. But the water must be previously clarified, for matter in suspension prevents the passage of the ultra-violet rays. The water flows through a series of tubes in which are placed lamps emitting ultra-violet rays. After passing before the first lamp the number of microbes was about 5250 per cubic centimetre, after passing the second lamp analysis showed no bacilli.

Preservation of Eggs in Cold Storage. (*Sci. Americ.*, xii, 17.)—A new system of treating eggs so as to prevent them from growing stale when in cold storage has been discovered in Rochester. This consists in subjecting the eggs to an electrical current. The theory is that eggs when placed in storage are alive and are gradually frozen to death, whereas if the life is destroyed by an electrical current before they are placed in storage they do not taste stale, even when kept on ice for a long period of time.

Electro-Metallurgy of Zinc. V. ENGELHARDT and M. HUTH. (*Metallurgie*, 1910, vii.)—The electrolytic refining of zinc is unprofitable. Copper refining yields valuable by-products in the noble metals. The Friedrich's-hütte factory tried to refine electrolytically the residue from the zinc-desilveration process, but it proved too expensive. Neither was Hopfner's electrolysis of zinc chloride economical. There remains the sulphate electrolysis. The ore is roasted, extracted with sulphuric acid, the solution purified and

then electrolyzed. Good zinc is only obtained from pure solutions. When hydrogen is evolved spongy zinc forms and is redissolved in the free acid. The chief trouble is the insoluble anode. Carbon is destroyed. Anodes of manganese peroxide are good.

An Electric-Lighting Plant Making Ice. (*Sci. Americ.*, xii, 17.)—An electric-lighting plant in Nebraska manufactures ice as a by-product. The exhaust steam of the plant, instead of going to waste, is utilized in the ammonia absorption process of ice manufacture, and also for distilling water from which the ice is made. The venture has proved very profitable for the lighting company and might be utilized by other plants similarly situated.

Reaction of Nascent Hydrogen. A. C. VOURNASOS. (*Comptes rendus*, 1910, 150.)—Nascent hydrogen liberated on heating dry sodium formate reacts with several elements which do not combine directly with free hydrogen.

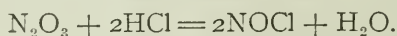
Phosphorus.—When sodium formate melted at 200°C . is subjected (after the air has been displaced by hydrogen) to phosphorus vapors obtained by heating phosphorus to 400° – 450°C ., phosphoretted hydrogen, mixed with phosphorus vapors, is readily formed. This gas is also formed when a mixture of 1 part of red phosphorus and 5 parts of sodium formate, or preferably an equimolecular mixture of sodium formate and hydroxide, is heated in a tubulated retort, after expelling the air by hydrogen, to 400°C .; or when a mixture of sodium formate and neutral sodium phosphite (or anhydrous disodium phosphate) is similarly heated.

Sulphur.—Hydrogen sulphide is obtained in a similar manner by heating 1 part of flowers of sulphur with 4 parts of an equimolecular mixture of sodium formate and hydroxide to 400°C ., as above. Sodium sulphite is also reduced with production of hydrogen sulphide. The sulphides of mercury, lead, and tin similarly treated yield their respective metals and hydrogen sulphide. *Arsenic* and sodium arsenite readily yield arseniuretted hydrogen. Sodium antimonite yields a little stibine. Silicon does not react, but its chloride and sulphide give a little hydrogen silicide. Nitrides yield ammonia; cyanides, hydrocyanic acid; alkali carbides yield acetylene, etc.

The Induction Generator. T. SPOONER and A. J. BARNES. (*Electrical World*, 1910, 55.)—The operation of induction generators in parallel with synchronous machines is discussed. An induction generator is simply an induction motor driven at a speed above synchronism. The voltage and frequency are governed respectively by the field strength and the speed of the synchronous apparatus. The first point investigated was the effect of short-circuit on the system. Oscillograph records are shown, illustrating what happens when the generator is short-circuited, when supplying energy to a

non-inductive load. Theory shows that a short-circuit is equivalent to a withdrawal of the exciting current, and hence the generator ought to produce no energy. This was found to be the case. Corresponding oscillograms are shown for the case when the generator was working on a capacity-load previous to the short-circuit. It is proved that induction generators have the following advantages: (1) They do not require the protection of cut-outs, as short-circuits do not harm them. (2) No large mechanical stresses are produced during short-circuit. (3) As soon as a short-circuit is removed, the generators work normally.

Chemical Reactions in Gases at High Pressures. E. BRINER and A. WROCZYNSKI. (*Comptes rendus*, 1909, 149.)—The authors find that when a mixture of 3 volumes NO and 1 volume HCl is subjected to a pressure of 300 atmospheres at the ordinary temperature, nitrosyl chloride is gradually formed. Further, under the same conditions, nitric oxide yields continually increasing quantities of nitrous oxide, decomposing according to the equation $3\text{NO} = \text{N}_2\text{O}_3 + \text{N}$. This decomposition evidently precedes the formation of nitrosyl chloride from nitric oxide and hydrogen chloride, the second stage being represented thus:



The Mallet Locomotive. (From *Scientific American*, cii, 17.)—The Mallet articulated compound locomotive continues to grow in favor; the reports from this type of locomotive in service are generally favorable. The N. Y. Central system has recently put a Mallet compound in service on the Boston and Albany line. The present class of heavy freight engine on that road has a maximum tractive power of 26 tons, whereas the Mallet, when working compound has 33 tons, when working simply 40 tons tractive power. The success of the type in freight service is undisputed. The future will tell what results it will give in fast passenger service.

Ozone in the Flame. W. MANCHOT. (*Ber.*, xlii.)—By the use of the reaction between Ag and O_3 the author demonstrates the presence of this gas in hot flames. The quantity is greatest in the hottest portions of the flame, which agrees with Nernst's calculations that the equilibrium between O_2 and O_3 favors the latter at high temperatures. The ozone can be detected in any very hot flame such as the oxyhydrogen or even the ordinary gas blast. But cooler flames, like CO burning in air, show little ozone, though CO burning in oxygen shows considerable, due to the higher temperature. The oxidation of Ag by O_3 gives a different appearance from that caused by oxides of nitrogen or H_2O_2 , and the reaction is therefore specific for O_3 . H_2O_2 can be detected in the flame by playing an oxyhydrogen blast directly against the surface of a concentrated Titanium solution, the yellow color appearing in a half minute.

Changing the Color of the Diamond. PAUL SACERDOTE. (*Comptes rendus*, 149.)—The author's results in a number of experiments on colorless and yellowish diamonds are: (1) The X-rays do not change the color of the diamond perceptibly. (2) The cathode rays of a vacuum tube changed the appearance of the diamond placed within the tube from colorless or pale yellow to the color of "Madeira wine" and finally to a more or less pronounced brown, dependent on the length of exposure. (3) This color is permanent and unaffected by direct sunlight. (4) A temperature of 300° to 400° C. removes this coloration.

Physiological Effects Produced by an Alternating Magnetic Field. S. P. THOMPSON. (*Comptes rendus*, cl, 16.)—Up to the present time it has been admitted that magnetism produces no physiological effect; it has been positively stated that if one's head is placed between the poles of a powerful electro-magnet, one feels no effect. However, by operating in an alternating field of sufficient force, a positive action is obtained, which was perceived by all who underwent the experiment. The field was produced by a coil of 32 turns of a copper wire, large enough to carry about 180 amperes; the coil was 8 inches long and 9 inches in diameter. The rate of the current was 50 per second. The maximum value of the field was 1400 units C.G.S. at the centre. On placing the head in this coil an observer perceived, in the dark or by closing the eyes, a weak and fluctuating light, either colorless or slightly bluish. The period of fluctuation is badly defined; and is more brilliant at the periphery than at the centre. Even in full daylight, with the eyes open, there is a sensation of a luminous fluctuation. These effects increase or diminish with the intensity of the electric current. The senses of hearing and smell are unaffected. Taste is affected in the same way as sight.

Agitation by Air and Steam. (*Power*, xxxii, 19.)—In some metallurgical operations steam is admitted to large tanks to produce agitation. In certain cases the consumption of steam is enormous and the quantity of steam can be greatly reduced and the agitation much increased by allowing the steam to carry in air through an injector. First turn on the steam, then open the valve of the injector until the desired amount of air is obtained.

Controlling a Ship's Water-tight Bulkhead Doors. (*Engineering*, lxxxix, 2313.)—The Stone-Lloyd system of controlling such doors by hydraulic power is becoming widely employed, owing chiefly to the absence of expense for upkeep and repair. This system is to be adopted in the large trans-Atlantic steamer *La France* and in the new Japanese dreadnought now building at Yokosuka. This vessel has 22 doors. The Japanese authorities accept the contention of the owners of the Stone-Lloyd system that hydraulic

power alone can be relied upon to work satisfactorily in the damp and dirt of stokeholds, that steam is dangerous, and that electricity is liable to fail at the critical moment, and dangerous where there is a possibility of fire-damp.

Hardening of Carbon and Low-Tungsten Tool-Steels. S. N. BRAYSHAW. (*Engineering*, lxxxix, 2313.)—Such steel has a long range of quite 120° C. (216° F.) within which it may be hardened to show a good fracture. The lower end of this range is very sharply defined but the highest temperature allowable is difficult to determine, and there is little evidence of bad work (so far as the appearance of the fracture is concerned) until the temperature of the hardening point has been exceeded by 150° C. (270° F.). In the light of the experiments recorded it is not to be supposed that most of the articles hardened by judging the temperature by sight alone, reach anything like their maximum efficiency, for slight variations in the heat treatment previous to quenching have a profound effect upon the condition of the steel, and the previous treatment by annealing or otherwise may powerfully influence the final result. It has been demonstrated that so far as bending tests are concerned it is easy to harden so as to produce a good bar, but the production of the best bar necessitates a degree of accuracy beyond what can be determined by sight alone; and the difference between good bars and the best bars is very great.

For some years the efforts of steel makers have been mainly directed towards the discovery of new alloys, and splendid success has been achieved. The time will come when all the factors in the hardening of tool-steel will be controlled with accuracy within predetermined limits, and any failure will be investigated, and the blame apportioned with as much certainty as if a mistake had been made in the machine shop.

The Weathering of Coal. S. W. PARR and W. F. WHEELER. (*Eng. Record*, 61, 18.)—Coal of the type found in Illinois and neighboring states is not affected seriously during storage when only the changes in weight and losses in heating powers are considered. The changes in weight may be either gains or losses of probably never over 2 per cent. in a period of one year. The heating value decreases most rapidly during the first week after mining, and continues to decrease more and more slowly for an indefinite time. In the coals tested 1 per cent. is about the average loss for the first week, and 3 to $3\frac{1}{2}$ per cent. would cover the losses for a year, although sometimes they reach 5 per cent. The losses due to disintegration and to spontaneous ignition seem to be of far greater importance, though they cannot be expressed in figures for comparison. The storage of coal of a size larger than is to be used would overcome part of this loss. The larger sizes of coal are also much less liable to take fire spontaneously. Storage under water

will largely prevent disintegration, and will absolutely prevent fire losses. Apart from this there seems to be very little in favor of any particular method of storing.

Passage of Bacteria Through Sand-Filters. RUDOLPH HERING. (*Eng. Record*, lxi, 18.)—The conclusion arrived at is that properly devised and operated filters will safely remove pathogenic bacteria, when the raw water is *not much* polluted. There appears to be sufficient evidence, however, that with a sufficient quantity of nutriment dissolved in the water, pathogenic bacteria not only *pass through* filters, but that their number may *actually increase* within them. With these facts in mind double filtration was proposed as a safeguard, and has been practised in Altona and Bremen in Germany for a number of years.

Fortunately we have now a remedy against the danger of escaping pathogenic bacteria by their direct destruction with calcium and sodium hypochlorite, which can be economically applied in connection with the filtration of water supplies, and also for sewage purification after the suspended organic matter has been substantially removed by filters or otherwise.

Iron Ore Deposits of Australia. J. BOWIE WILSON. (*Eng. and Min. Journal*.)—One of these is on Iron Island, about 10 miles off the coast of Queensland. In the past three years about 90,000 tons of ore have been shipped. A sample showed iron 64-72 per cent., silica 2.51 per cent., alumina 2.95 per cent., lime 2.85 per cent., magnesia 1.07 per cent., and phosphorus 0.065 per cent. The other is on Koolan Island, off the west coast. The iron ore is on the south side; it is anhydrous and has a black metallic lustre and contains iron 66.48 per cent., silica 4.16 per cent., sulphur 0.072 per cent., phosphorus 0.064 per cent.

The Briey Iron Ore Deposits. (*Iron Age*, lxxxv, 15.)—These deposits in Briey, France, are the continuation of those in German Lorraine and Luxemburg. The whole deposit covers about 328 square miles, of which about 150 are in German Lorraine, the same in France, and the remainder in Luxemburg. It is estimated that the Lorraine-Luxemburg deposits contain 2700 million tons of ore. French Lorraine contains about 1300 million tons. Mining in the Briey basin is at a maximum depth of about 900 to 1000 feet. It is probable that at least a dozen German companies have bought or leased ore properties in this region.

Fluxes from the Viewpoint of the Metallurgist. L. J. KROM. (*Met. Ind.*, viii, 5.)—*Sal ammoniac*, or ammonium chloride, is particularly well adapted as a flux for zinc and aluminum. *Zinc chloride* is good for aluminum and its alloys, and does not affect the crucible. *Borax*, or sodium biborate, is good for easily oxidizable metals such as nickel, zinc, and copper; it attacks the crucible only to a small extent. *Calcium fluoride*, or fluorspar, alone or with

an equal quantity of lime, is useful for fluxing nickel or German silver. This strongly attacks the crucible. *Potassium cyanide* is an excellent flux for producing sound castings of copper, but is destructive to the crucible and is expensive and poisonous. *Potassium ferrocyanide* is well adapted for copper casting, but is likely to introduce some iron into the metal, so should only be used at the last minute before pouring. It is less expensive and not so poisonous as the cyanide. *Sodium carbonate* is a good flux for metal bearing material, but lime and fluorspar are better. *Magnesium sulphate*, or plaster of Paris, is used for the recovery of metals from sweepings and waste materials. *Potassium nitrate*, or saltpeter, is used extensively in the manufacture of German silver. It attacks the crucible rapidly. Its best application is as a flux for purifying gold and silver, by oxidation. *Glass, mercury bichloride*, and *potassium bisulphate* are also used as fluxes.

A New Process of Galvanizing. (*The Metal Ind.*, viii, 3.)—A new process resembling sherardizing has been patented (U. S. Pat. No. 928,398). The iron or steel to be galvanized is coated with a paste composed of

Zinc flue dust	88 parts,
Lampblack	2 parts,
Clay	10 parts.

The ingredients are mixed with water and applied to the cleaned iron or steel surface. The whole is placed in a furnace and heated to a temperature of from 600° F. to 1000° F. for a period varying from one-half to four hours.

Permissible Explosives as Used in Coal-Mines. J. J. RUTLEDGE. (*Eng. and Min. Jour.*, 1910, lxxxix.)—Owing to numerous disastrous explosions in coal-mines in the United States believed to be due to the use of black blasting powder, the manufacture of permissible explosives has rapidly increased of late. These explosions, and the work of the Pittsburg Testing Station, have greatly extended the use of permissible explosives in the mining districts. There are three varieties of permissible explosives: the ammonium nitrate class; the nitro-glycerin class; and the hydrated class. These explosives are usually fired by electric detonators. One of their advantages is that they can be used in wet or damp holes. Another advantage is the absence of smoke, when properly fired; the miners are able to return to the place in about 30 seconds after the shot, without discomfort from the fumes. The objections to their use are: (1) they freeze at a rather high temperature; (2) they cost more per ton of coal produced than black powder; (3) some of them deteriorate rapidly on exposure to the atmosphere.



International Arbitration and Peace. The Mission of America in the Politics of the World. In the House of Representatives. Extract from the Congressional Record. 16 pages, 8vo. Washington, 1909.

National Association of Cotton Manufacturers. Advance copies of papers to be read at the Annual meeting, No. 88, Boston, Mass., April 27-28, 1910. 16 pamphlets, illustrations, 8vo.

A New Theory on the Pacific Coast Climate. By Sereno E. Bishop. (Reprinted from Honolulu Chamber of Commerce Annual for 1909.) 7 pages, 8vo. Honolulu, Hawaii Promotion Committee, n. d.

Wissenschaftliche Abhandlung über das Theorem des Mathematikers Fermat $x^n + y^n = z^n$. Von O. Heck zu Selters in Oberhessen. 16 pages, 12mo. Büdingen, Büdinger Tageblatt, 1909.

Waterways—The Atlantic Coast Trunk-Line. Speech of Hon. J. Hampton Moore of Pennsylvania in the House of Representatives, Tuesday, July 27, 1909. 14 pages, 8vo. Washington, 1909.

U. S. House of Representatives, Committee on Agriculture. A report on "The Influence of Forests on Climate and on Floods," by Willis L. Moore, LL.D., Sc.D., Chief of the U. S. Weather Bureau. 38 pages, illustrations, maps, 8vo. *Washington, Government Printing Office, 1910.

Canada Department of Mines. Preliminary Report on the Mineral Production of Canada During the Calendar Year 1909, prepared by John McLeish, B.A. 18 pages, 8vo. Ottawa, Government Printing Bureau, 1910.

Canada Department of Mines. Iron Ore Deposits of Vancouver and Texada Islands, British Columbia, by Einar Lindeman, M.E. 29 pages, maps, 8vo. Ottawa, Government Printing Bureau, 1910.

Canada Department of Mines. Joint Report on the Bituminous, or Oil-Shales of New Brunswick and Nova Scotia; also on the Oil-Shale Industry of Scotland. Pt. I, Economics; Pt. II, Geology. By R. W. Ellis, LL.D., F.R.S.C. 75 pages, illustrations, plates, 8vo. Ottawa, Government Printing Bureau, 1910.

Designing Data for the Use of Expanded Metal and Expanded Metal Lath as Manufactured by the Northwestern Expanded Metal Company. 70 pages, illustrations, 16mo. Chicago, Company, 1910.

Report of the Commissioner of Education for the Year Ended June 30, 1909. Volumes i and ii, 1373 pages, 8vo. Washington, Government Printing Office, 1909-10.

U. S. Department of Commerce and Labor, Coast and Geodetic Survey. Results of Observations made at the Coast and Geodetic Survey Magnetic Observatory at Sitka, Alaska, 1905-1906, by Daniel L. Hazard. 115 pages, illustrations, 4to. Washington, Government Printing Office, 1910.

Argentine Republic. Centenary of the Revolution of May 1810. Argentine Scientific Society. International American Scientific Congress to be held in Buenos Aires from the 10th to the 25th July 1910. Bulletin No. 1. 43 pages, 8vo. Buenos Aires (n.d.).

American Telephone and Telegraph Company. Annual Report of the Directors to the Stockholders for the Year Ending December 31, 1909. 40 pages, 8vo. Boston, Ellis Co., 1910.

University of Kansas, Bulletin, vol. ii, No. 1. Engineering Bulletin No. 1. A Ballistic Electrodynamometer Method of Measuring Hysteresis Loss in Iron, by Martin E. Rice and Burton McCollum. Voltage Regulation of Alternators, by Burton McCollum. 23 pages, illustrations. Lawrence, Kansas, University, November, 1909.

Cleveland Engineering Society, Journal. Volume ii, Nos. 2 and 3, 8vo. Cleveland, Ohio, Society, December 1909, March 1910.

The Spectroscopic Camera. Notes on the Use of the Spectroscopic Camera, designed by Alex. A. K. Tallent, author of Trichromatic Section of "A Handbook of Photography in Colors." 20 pages, illustrations, plates, oblong 32mo. London, A. W. Penrose & Co., Ltd. (n.d.).

Special Libraries. Volume i, No. 2. 8 pages, 8vo. New York, Special Libraries Association, February, 1910.

Michigan State Board of Health. Thirty-sixth Annual Report for the Fiscal Year Ending June 30, 1908. 222 pages, 8vo. Lansing, State Printers, 1909.

Les Mathématiques en Portugal. Deuxième Défense, Travaux de Antonio Cabreira. 118 pages, 8vo. Lisbonne, L'Auteur, 1910.

United States Geological Survey. Mineral Resources of the United States. Calendar year 1908. Part I, Metallic Products; Part II, Non-metallic Products. 2 vols, 8vo. Washington, Government Printing Office, 1909.

Ontario Bureau of Mines. General Index to the Reports of the Bureau. Volumes i to xvi (1891-1907). Compiled by Frank J. Nicolas. 466 pages, 8vo. Toronto, King's Printer, 1909.

National Association of Cotton Manufacturers, Transactions No. 86. Annual Meeting held at Boston April 29-30, 1909. 556 pages, illustrations, 8vo. Boston, Association, 1909.

University of Illinois Bulletin, vol. vi, No. 3. The Mineral Content of Illinois Waters, by Edward Bartow, J. A. Udden, S. W. Parr, and George T. Palmer. Water Survey Series No. 4. 192 pages, 8vo. Urbana, University, September 15, 1908.

Armour Institute of Technology, Bulletin (new series), vol. iii, No. 1. General Information number. 174 pages, 8vo. Chicago, Institute, May, 1909.

Ontario Bureau of Mines. Eighteenth Annual Report, 1909. Volume xviii, Part I. 311 pages, illustrations, maps, 8vo. Toronto, King's Printer, 1909.

Dactiloscopia Argentina su historia é influencia en la legislacion por Luis Reyna Almandos. Contribucion al IV Congreso Cientifico Latino Americano (1er Pan-Americano). 271 pages, plates, tables, 8vo. LaPlata, Joaquin Sesé, 1909.

U. S. Census Bureau. Forest Products, No. 2. Lumber, Lath, and Shingles, 1908. 57 pages, 8vo. Forest Products, No. 5: Veneers, 1908. Forest Products, No. 6: Tight Cooperage Stock, 1908. Forest Products, No. 7: Wood Distillation, 1908. Forest Products, No. 10: Forest Products of the United States. 5 pamphlets, 8vo. Compiled in co-operation with the Department of Agriculture. Washington, Government Printing Office, 1909.

The JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

AUGUST, 1910

No. 2

RECENT PROGRESS IN THE CHEMISTRY OF THE SUGARS.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.,

Secretary of the Section.

*(Presented at a Stated Meeting of the Section of Physics and Chemistry,
held Thursday, May 12, 1910.)*

[This paper reviews the work of Emil Fischer upon sugars and ferments. The syntheses of monoses, disaccharides and glucosides are described. The fermentation of the sugars and the action of the various inverting enzymes are discussed, as is also the lock-and-key theory of enzyme action. The splitting of racemic sugar derivatives into their active components, and asymmetric syntheses within the sugar group are also considered.]

Foods fall into three great divisions, the fats and oils, the carbohydrates or sugars, and the proteins or nitrogenous foods. Of the three classes, the sugars are in a sense the most important, for plants synthesize carbohydrates from the carbon dioxide of the air by means of their chlorophyll; the carbohydrates thus produced may serve as a source of fat and protein. Exact experiments upon metabolic assimilation have shown that formation of fat from carbohydrate occurs in the animal body; in the vegetable world, the unripe seeds of certain plants like rape and the peony contain large quantities of starch and sugar, which entirely disappear and are replaced by oil, when the seeds ripen or even upon storage after the removal of the seeds from the

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

VOL. CLXX, NO. 1016—7

85

mother plant. This transformation of carbohydrate in which at first appears rather complicated, is in fact quite simple. Glucose contains a normal chain of six carbon atoms, and by oxidation and reduction, one molecule of glucose may give rise to two molecules of glycerol. By condensation of three molecules of glucose, accompanied by reduction and the formation of a carboxyl group, stearic and oleic acids, with their normal chains of eighteen carbon atoms, may be formed. In a similar way palmitic acid, which contains a normal chain of sixteen carbon atoms, may be formed by the condensation of one molecule of hexose and two molecules of pentose, although the union of three hexose molecules, followed by the elimination of two carbon atoms, would also give rise to palmitic acid. By the union of glycerol and the fatty acids, the fats and oils are then produced. Proteins are synthesized by plants from carbohydrates and inorganic nitrogen and sulphur compounds.¹

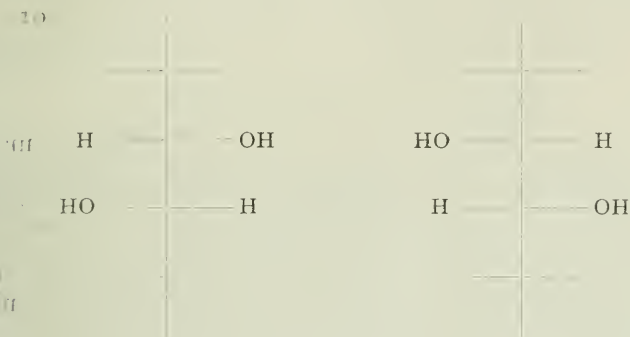
Through the labors of Chevreul and others, the chemical nature of the fats and oils was early recognized. While the proteins have been the subject of many researches, the investigation of these compounds from the standpoint of pure chemistry and their synthesis are the work of Emil Fischer, whose investigations upon amino acids, polypeptides, and proteins were recently reviewed before the Section by Dr. Bradbury.² From time to time the sugars and their derivatives have attracted the attention of chemists, witness Scheele's work upon mucic acid.—the "acid of sugar of milk,"³ and the study of amygdalin and emulsin by Liebig and Wöhler.⁴ However, the synthesis of the sugars, the deduction of their configuration, and the demonstration of their relation to each other is a triumph of the last quarter of a century and is due to Emil Fischer. In his investigations upon the sugars, Fischer has not confined himself within the boundaries of chemistry, but has also entered the domain of biology, in his studies of the action of enzymes upon the sugars and their derivatives.

NOMENCLATURE OF THE SUGARS.⁵

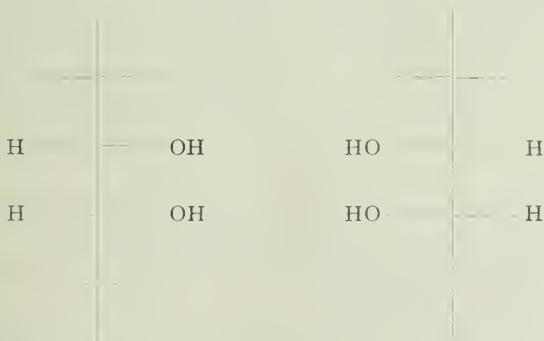
The sugars fall into two groups, the monoses and the polyoses. The monoses or simple sugars are either aldehyde-alcohols (aldoses), or ketone-alcohols (ketoses); they have the general

and $C_nH_{2n}O_n$, and contain from two to nine carbon atoms in the molecule, whence they are called diose, triose, tetrose, pentose, hexose, heptose, octose, nonose. Thus glucose is an aldohexose, fructose a ketohexose.

The letters d- (dextro) and l- (laevo), applied to a monose or its derivatives, denote the configuration of that sugar. The hexoses fall into two series, the mannite series and the dulcite series. Each of these series has a characteristic configuration at the β and γ carbon atoms, as may be seen in the following projection formulæ:



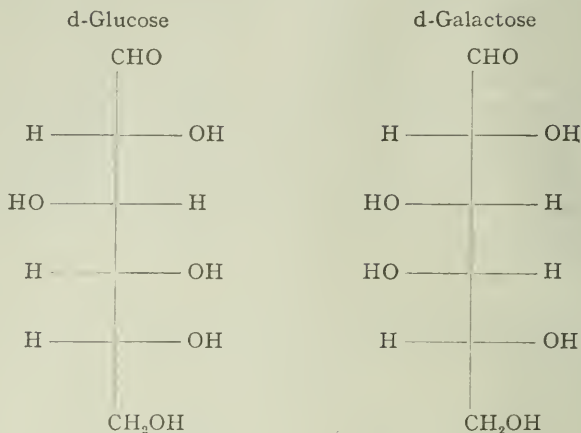
Mannite Series



Dulcite Series

The hexoses of the mannite series derive their configuration and designation of dextro or laevo from their relation to d-glucose, while the configuration and designation d- or l- are deter-

mined for the hexoses of the dulcitate series by their relation to d-galactose.



The configuration and designation d- or l- of any monose which contains more or less than six carbon atoms are determined by the relation of that monose to an aldohexose.

Both true racemic compounds and mixtures of optical antipodes in equimolecular proportions are optically inactive by external compensation, although they contain asymmetric carbon atoms. Such compounds are designated by the letters dl-.

All compounds, which are dextro in configuration, are not dextro rotatory, *e.g.*, d-fructose is laevo rotatory and l-xylose is dextro gyrate. In order to overcome this apparent ambiguity, Fischer⁶ has recently devised the following series of symbols, which denote both configuration and rotatory power:

d- and l-, symbols for rotatory power alone, when the configuration is unknown, *e.g.*, l-leucine, d-lactic acid.

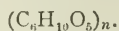
d°, symbol for dextro configuration and dextro rotation, *e.g.*, d°-glucose, d°-mannose.

l°, symbol for laevo configuration and laevo rotation, *e.g.*, l°-glucose, l°-mannose.

d', symbol for dextro configuration and laevo rotation, *e.g.*, d'-fructose.

l', symbol for laevo configuration and dextro rotation, *e.g.*, l'-xylose.

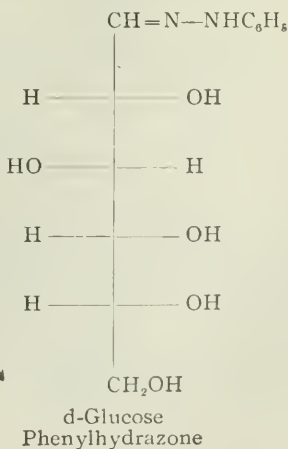
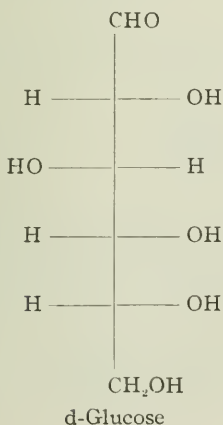
Of the polyoses, only certain disaccharides or hexabioses,—compounds of the formula $C_{12}H_{22}O_{11}$,—have been synthesized. Their molecular formula shows that they are formed by the union of two hexose molecules with the elimination of one molecule of water. In mode of synthesis and in certain of their reactions, the disaccharides resemble the synthetic glucosides. The higher polyoses have the formula

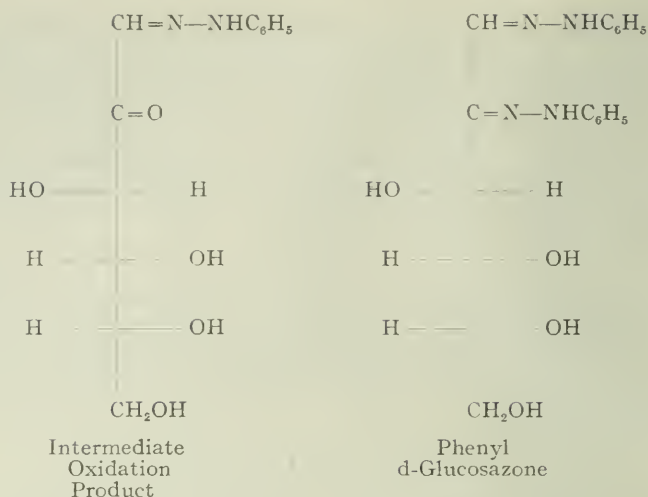


This group includes starch, cellulose, and glycogen,—derivatives of d-glucose; inulin,—a derivative of d-fructose; and the reserve cellulose of the vegetable ivory nut,—a derivative of d-mannose. The pentoses occur in Nature as polyoses known as pentosans.

THE REACTIONS OF THE MONOSES.

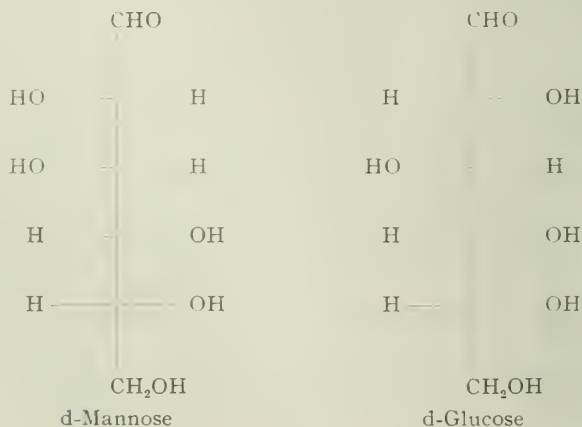
The monoses and those disaccharides which are reducing sugars form characteristic compounds with phenylhydrazine.⁷ This reagent first reacts in the cold with the carbonyl group of the sugar to form a phenylhydrazone,—a reaction common to all aldehydes and ketones. The phenylhydrazones of the sugars are usually soluble in cold water; the phenylhydrazones of d-mannose,⁸ l-mannose,⁹ and of certain monoses of higher carbon content (α -glucooctose, glucononose¹⁰; d-mannoheptose, d-mannooctose, d-mannononose¹¹; α -galaheptose, galaoctose¹²; l-mannoheptose¹³, and rhamnoheptose¹⁴) form exceptions to this rule, for they are insoluble or difficultly soluble in water of ordinary temperature.

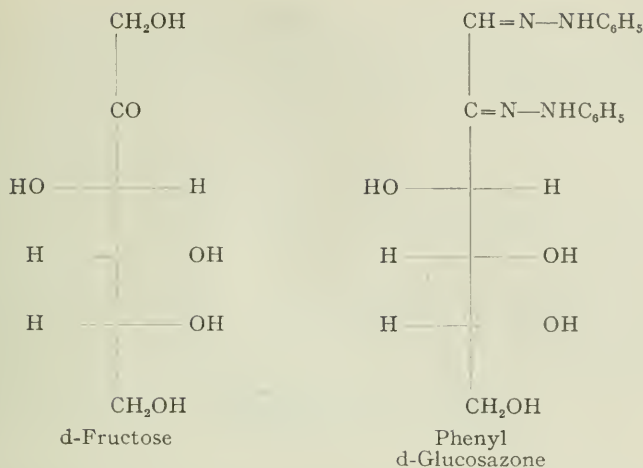




At the temperature of the water-bath, the reaction proceeds a step farther and a compound, known as an osazone, is produced. The alcohol group, which is in the α position to the original carbonyl group, is itself oxidized to a carbonyl group by the phenylhydrazine, which is reduced to aniline and ammonia. This newly formed carbonyl group immediately combines with phenylhydrazine to form the osazone.

When several sugars differ in configuration only at the α carbon atom, they will yield the same osazone, thus d-glucose, d-mannose and d-fructose all give rise to phenyl d-glucosazone.





In a similar way, d-galactose and d-talose yield the same osazone,—phenyl d-galactosazone.¹⁵ The osazones are crystalline compounds, and are useful in the separation and identification of the sugars. The molecular formula of a sugar may be determined by means of its osazone. By elementary analysis the empirical formula CH_2O is deduced for both d-mannose and d-mannoheptose. However, upon elementary analysis of the osazones of these sugars, the molecular formulæ are found to be:

Phenyl d-Glucosazone (osazone of d-Mannose), $\text{C}_{18}\text{H}_{22}\text{N}_4\text{O}_4$;

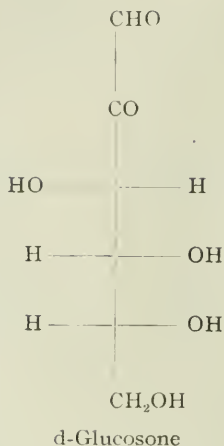
Phenyl d-Mannoheptosazone, $\text{C}_{19}\text{H}_{24}\text{N}_4\text{O}_5$;

whence the molecular formulæ of the corresponding monoses:

d-Mannose, $\text{C}_6\text{H}_{12}\text{O}_6$;

d-Mannoheptose, $\text{C}_7\text{H}_{14}\text{O}_7$.

The osazones are usually insoluble even in hot water; the osazones of the disaccharides, maltose and lactose, are soluble in hot water and insoluble in cold water. Ice-cold concentrated hydrochloric acid¹⁶ decomposes the osazones; phenylhydrazine hydrochloride and a series of new compounds, the osones, result; for instance, from phenyl d-glucosazone is obtained d-glucosone:



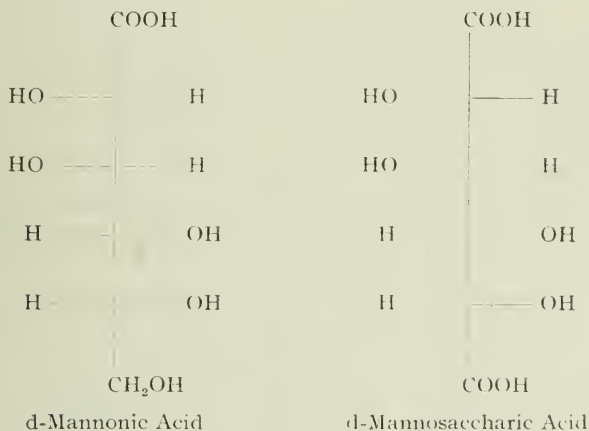
Since hydrochloric acid may hydrolyze the osone of a disaccharide, a special method has been devised in order to prepare the osones of the disaccharides from the corresponding osazones. The aqueous solution of the osazone is boiled with benzaldehyde; a soluble osone and insoluble benzaldehyde phenylhydrazone are formed,¹⁷ thus maltosazone gives rise to a solution of maltosone.

d-Glucosone is reduced to d-fructose by the action of zinc dust and acetic acid.¹⁸ Hence d-glucose, an aldose, may be converted into phenyl d-glucosazone, then into d-glucosone, and the latter may be reduced to d-fructose, a ketose; *i.e.*, an aldose may be transformed into a ketose of the same carbon content.

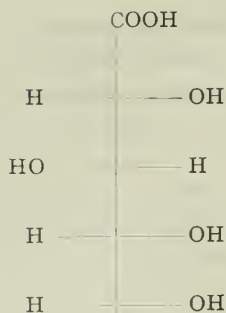
The oxidation and reduction products of the monoses are of great importance. Sodium amalgam reduces both aldoses and ketoses to the corresponding polyhydric alcohols; the earlier stages of the reduction are carried out in dilute sulphuric acid solution and the later stages in a weakly alkaline solution; thus d-mannose reduces to d-mannite⁸ and d-fructose reduces to d-mannite and d-sorbite.¹⁹ The polyhydric alcohols may be oxidized to sugars; the usual oxidizing agents are bromine and sodium carbonate, and nitric acid. Bromine and sodium carbonate give rise to a mixture of aldose and ketose, while aldose chiefly is formed by the action of nitric acid.²⁰ Thus d-mannite is oxidized to d-mannose by nitric acid at the temperature of the water bath,²¹ and glycerol in aqueous solution is converted by sodium carbonate and bromine at room temperature into glyce-

rose²²—a mixture of glyceraldehyde and dioxyacetone.²³ These reactions make possible the transition from a ketose to an aldose of the same carbon content, *e.g.*, d-fructose, a ketose, yields on reduction d-mannite, which furnishes d-mannose, an aldose, when oxidized by nitric acid.

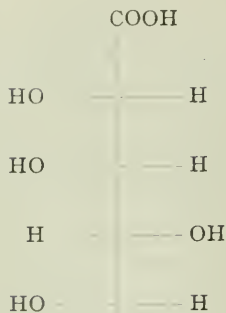
Upon oxidation, the ketoses give rise to compounds of lesser carbon content. An aldose upon oxidation passes first into a monocarboxylic acid, then into a dicarboxylic acid; both acids contain the same number of carbon atoms as the sugar from which they are derived. Thus d-mannose in aqueous solution is oxidized to d-mannonic acid by bromine at room temperature,²⁴ while nitric acid of specific gravity 1.2, aided by gentle heat, oxidizes d-mannose to d-mannosaccharic acid.²⁵



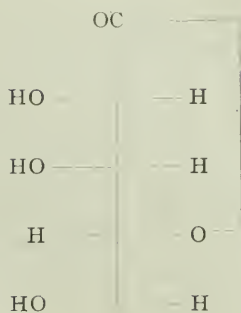
Upon evaporation of their aqueous solution, the monocarboxylic acids and certain of the dicarboxylic acids form lactones. These lactones are reduced by sodium amalgam in the presence of dilute sulphuric acid; cooling and shaking are essential for proper reduction. The lactones of monocarboxylic acids are reduced to aldoses, thus d-mannonic lactone reduces to d-mannose.²⁶ d-Saccharic acid is the dicarboxylic acid derived from d-glucose; it forms a lactone which reduces to glucuronic acid,—an aldehyde acid,—then to d-gulonic acid; the latter forms a lactone which yields d-gulose upon reduction.²⁷



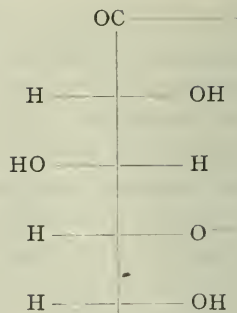
COOH
d-Saccharic
Acid



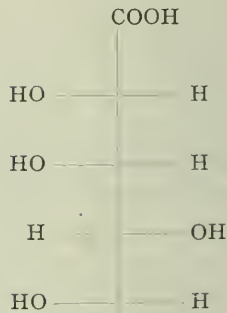
CHO
Glucuronic
Acid



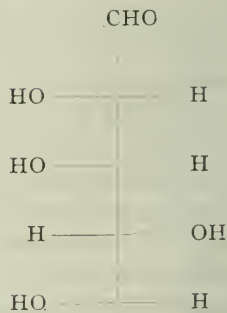
CH₂OH
d-Gulonic
Lactone



COOH
d-Saccharic
Lactone



CH₂OH
d-Gulonic
Acid



CH₂OH
d-Gulose

When a monocarboxylic acid is heated with quinoline at $140^{\circ}\text{C}.$ ²⁸ or with aqueous pyridine under pressure at $140^{\circ}\text{C}.$ ²⁹, a partial transposition of the hydrogen atom and hydroxyl group occurs at the carbon atom which is in the α position to the carboxyl group. The partial transformation of the pentonic acids is carried out at a lower temperature, thus l-arabonic acid undergoes a partial change into l-ribonic acid at $130^{\circ}\text{C}.$ ³⁰ and l-xylonic acid into d-lyxonic acid at $135^{\circ}\text{C}.$ ³¹ If two sugars differ in configuration only at the α carbon atom, this rearrangement makes possible the transition from the one sugar to the other, thus d-glucose may be oxidized to d-gluconic acid, which is partially transformed into d-mannonic acid when heated to $140^{\circ}\text{C}.$ with quinoline; the lactone of d-mannonic acid is then reduced and d-mannose is obtained. In like manner d-mannose may be converted into d-glucose.

The cyanhydrin synthesis of Kiliani³² has found wide application in the preparation of synthetic sugars. The reducing sugars add hydrocyanic acid at the carbonyl group at room temperature in the presence of a slight quantity of ammonia and form cyanhydrins, which frequently undergo either partial or complete saponification spontaneously; thus d-mannose cyanhydrin becomes d-mannoheptonic amide³³ and d-glucose cyanhydrin becomes the ammonium salt of glucoheptonic acid.³² The saponification is completed by warming with baryta water; the acid is liberated and converted into its lactone, which is reduced to an aldose. Thus d-mannose gives rise to d-mannoheptonic acid and its lactone, this lactone reduces to d-mannoheptose; an aldohexose has been converted into an aldoheptose; by the same procedure d-mannoheptose may be converted into d-manno-octose, and the latter into d-mannononose. Hence by means of this synthesis, one may pass from any reducing sugar to its higher homologues.

Ruff³⁴ has discovered a reaction which makes possible the transition from an aldose to its lower homologues. The aldose is oxidized to its monocarboxylic acid and the latter is converted into its calcium salt. Hydrogen peroxide reacts with this calcium salt in the presence of basic ferric acetate and forms a new aldose, the next lower homologue of the original aldose; water and carbon dioxide are the other products of the reaction; e.g., d-glucose is converted into d-gluconic acid, then into cal-

cium d-gluconate; the latter, upon reacting with 1.19 per cent. hydrogen peroxide and basic ferric acetate, gives rise to d-arabinose, the optical antipode of natural l-arabinose.

The aldoses possess an asymmetric molecular structure, *i.e.*, the two terminal groups are unlike, hence the number of isomeric aldoses of any given carbon content is expressed by the formula 2^n , in which n represents the number of asymmetric carbon atoms in the molecule. The polyhydric alcohols and the dicarboxylic acids have a symmetric molecular structure, *i.e.*, the two terminal groups are alike, and the number of isomers is expressed by the formula of van t' Hoff $2^{\frac{n}{2}-1} (2^{\frac{n}{2}} + 1)$ when n is even, and by the formula of Fischer 2^{n-1} when n is uneven. Hence eight aldopentoses and four trioxylglutaric acids are possible, for three asymmetric carbon atoms are present. The aldohexoses and their acids contain four asymmetric carbon atoms, therefore sixteen aldohexoses and ten tetrahydroxy-dicarboxylic acids are possible.²⁰

THE HEXOSES.

Theory calls for eight aldohexoses in the mannite series, the entire eight isomers have been prepared; they fall into four sets of optical antipodes, d- and l-glucose, d- and l-mannose, d- and l-gulose and d- and l-idose.

d-Glucose has been synthesized by the reduction of d-gluconic lactone.²⁶ d-Glucose is found in Nature in honey and fruits and, as a polyose, in starch, cellulose and glycogen.

d-Mannose is formed by the oxidation of d-mannite with nitric acid.²¹ As a polyose it occurs in the salep bulb³⁵ and in reserve cellulose, *e.g.*, in the ivory-nut.³⁶

d-Gulose is prepared by the reduction of d-gulonic lactone, which is obtained by the reduction of d-saccharic lactone.²⁷

d-Idose results upon the reduction of the lactone of d-idonic acid; this acid is obtained from d-gulonic acid by heating the latter with aqueous pyridine under pressure at 140° C.³⁷

The optical antipodes of these four hexoses are obtained by application of the cyanhydrin synthesis to the pentoses, and subsequent reduction of the lactones of the hexonic acids thus produced. Thus l-arabinose gives rise to l-mannonic and l-gluconic acids, which are separated by the crystallization of their lactones; l-mannonic lactone crystallizes first, while l-gluconic lactone re-

mains in the mother liquor.³⁸ Upon reduction these lactones yield l-mannose⁹ and l-glucose³⁸ respectively. In like manner l-xylose gives rise to l-gulonic and l-idonic acids; l-gulonic lactone crystallizes first, while l-idonic lactone remains in the mother liquor.³⁷ Upon reduction the lactones are converted into l-gulose³⁹ and l-idose³⁷ respectively.

Aldohexose	Dicarboxylic Acid
d-Glucose	} d-Saccharic
d-Gulose	
l-Glucose	} l-Saccharic
l-Gulose	
d-Mannose	d-Mannosaccharic
l-Mannose	l-Mannosaccharic
d-Idose	d-Idosaccharic
l-Idose	l-Idosaccharic
d-Galactose	} Mucic
l-Galactose	
d-Talose	d-Talomucic

Two ketohexoses of the mannite series,—d-fructose and l-fructose,—have been synthesized. d-Fructose, which occurs in Nature as “fruit sugar,” is formed synthetically by the reduction of d-glucosone;¹⁸ l-Fructose remains when beer yeast ferments: α -acrose (dl²-fructose).⁹

But three aldohexoses of the dulcite series,—d-galactose, l-galactose and d-talose,—have been produced by synthesis. al-

though eight aldohexoses of this series are theoretically possible. By means of the cyanhydrin synthesis d-lyxose may be converted into d-galactonic acid and d-talonic acid; these acids are separated by means of their cadmium salts; after cadmium d-galactonate has crystallized, the d-talonic acid is found in the mother liquor.⁴⁰ Upon reduction the lactone of d-galactonic acid yields d-galactose,⁴¹ while d-talonic lactone gives rise to d-talose.¹⁵ d-Talonic acid is usually prepared by heating d-galactonic acid under pressure with aqueous pyridine at 150° C.¹⁵ d-Galactose occurs combined with d-glucose in the natural disaccharide lactose or milk sugar.

Both the lactone and diethyl ester of mucic acid form dl-galactonic acid upon reduction; further reduction of dl-galactonic lactone gives rise to dl-galactose, from which l-galactose is obtained by fermentation with beer yeast.⁴²

Theoretically ten dicarboxylic acids may be derived from the aldohexoses; all have been prepared. The table on page 97 shows the dicarboxylic acids obtained by oxidation of the aldoses.

The remaining isomers l-talomucic acid and allomucic acid have been prepared; they may be considered as derivatives of sugars which have not yet been synthesized. l-Talomucic acid is obtained by the oxidation of β -rhamnohexonic acid with nitric acid,⁴³ while allomucic acid is formed by heating mucic acid under pressure with aqueous pyridine at 140° C.²⁹

MONOSES CONTAINING MORE OR LESS THAN SIX CARBON ATOMS.

Six aldopentoses are known, the two arabinoses, the two xyloses, l-ribose and d-lyxose. l-Arabinose and l-xylose occur in Nature as pentosans. The preparation by Ruff of d-arabinose by the oxidation of calcium d-gluconate with hydrogen peroxide in the presence of basic ferric acetate has already been described. In a similar manner, Fischer and Ruff have prepared d-xylose from calcium d-gulonate.⁴⁰ Upon heating under pressure with aqueous pyridine, l-arabonic acid and l-xylonic acid are partially converted respectively into l-ribonic acid and d-lyxonic acid. The lactone of l-ribonic acid reduces to l-ribose,³⁰ while that of d-lyxonic acid reduces to d-lyxose.³¹

Erythrose, a tetrose, is formed when the tetrahydric alcohol erythrite is oxidized with nitric acid. It is probably a mixture of aldose and ketose.⁴⁴

Glycerose,⁴⁵ a triose, is a mixture of glyceraldehyde and dioxycetone. It may be prepared by the oxidation of glycerol by nitric acid of specific gravity 1.18 at the temperature of the water-bath, or of the aqueous solution of glycerol by sodium carbonate and bromine at room temperature; it is formed by the action of dry bromine on the dry lead salt of glycerol, $C_3H_6O_3Pb$. At $0^\circ C.$, in the presence of 1 per cent. sodium hydroxide, the aqueous solution of glycerose undergoes a polymerization with the formation of two hexoses, α - and β -acrose. These hexoses also result from the action of ice-cold baryta water upon acrolein bromide,⁴⁶ which is both saponified and polymerized; α -acrose is present in the polymerization product which is obtained by the action of lime water upon formaldehyde.⁴⁷ α -Acrose is dl-fructose.⁹

The diose, glycollaldehyde,⁴⁸ is the simplest sugar and is the only aldose that does not contain an asymmetric carbon atom. Its synthesis occurs in several stages. Upon treatment with bromine in the presence of calcium carbonate, the acetal of acetaldehyde is converted into the acetal of monobromacetaldehyde, from which the latter aldehyde is then isolated by distillation with anhydrous oxalic acid at the temperature of the oil-bath. Monobromacetaldehyde reacts with baryta water at $0^\circ C.$ to form glycollaldehyde. Under the influence of 1 per cent. sodium hydroxide solution, glycollaldehyde is converted into a polymer, a tetrose. This tetrose forms an osazone, the properties of which are the same as those of phenylerythrosazone.

Higher monoses have been obtained from d-mannose,¹¹ l-mannose,¹³ d-glucose¹⁰ and d-galactose¹² by means of the cyanhydrin synthesis, combined with subsequent reduction of the lactones of the acids thus produced. d-Mannose gives rise to d-mannoheptose, d-mannooctose and d-mannononose, while l-mannoheptose has been obtained from l-mannose. From d-glucose are derived α - and β -glucoheptose; from α -glucoheptose, α - and β -glucooctose; from α -glucooctose, glucononose; the monocarboxylic acid of a second glucononose is also known. From d-galactose are obtained α - and β -galaheptose, and from α -galaheptose is obtained galaoctose.

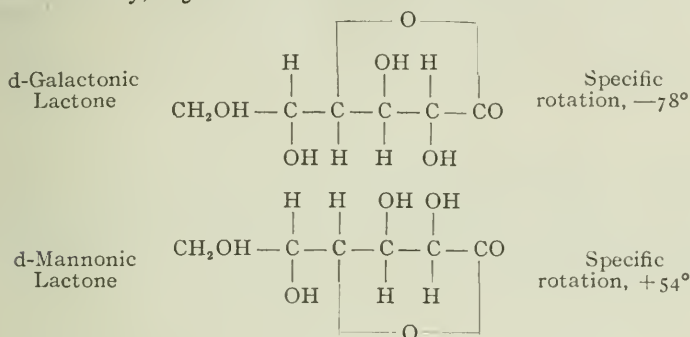
Volemose⁴⁹ is a heptose; it results upon the oxidation of volemite, the heptite of the mould *Lactarius volemus*, by means of nitric acid of specific gravity 1.14 at $50^\circ C.$, or of bromine and aqueous solution of sodium carbonate at $0^\circ C.$

RHAMNOSE AND ITS DERIVATIVES.

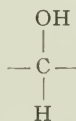
Several methyl pentoses occur in Nature, *e.g.*, rhamnose,⁵⁰ chinovose,⁵¹ fucose. Rhamnose or isodulcite, which is a constituent of the glucoside quercetrin, is the most important of these compounds. A method, devised by Wohl, has been used by Fischer for the preparation of methyl tetrose.⁵² The oxime of rhamnose is treated with acetic anhydride and sodium acetate in order to obtain the tetracetyl derivative of rhammonic nitrile; this compound is converted by ammoniacal silver oxide into a double compound of methyl tetrose and acetamide, from which the methyl tetrose is liberated by warming with dilute hydrochloric acid. A series of higher monoses, α -rhamnohexose, rhamnoheptose and rhamnooctose, have been obtained from rhamnose by means of the cyanhydrin synthesis, followed by reduction of the lactones of the acids thus formed.¹⁴ Rhamnose in aqueous solution is oxidized by bromine to a monocarboxylic acid (rhammonic acid),⁵³ which is partially transformed into isorhammonic acid when heated with aqueous pyridine under pressure at 150–155° C.; isorhammonic lactone reduces to isorhamnose. By a similar series of reactions, α -rhamnohexonic acid gives rise to β -rhamnohexonic acid,⁴³ β -rhamnohexonic lactone and β -rhamnohexose. Rhamnose then has practically all the properties of the monoses; however, one property is lacking, for upon oxidation with nitric acid the sugar yields not a dicarboxylic acid with the same number of carbon atoms, but l-trioxyglutaric acid, which contains one carbon atom less than rhamnose; the terminal methyl group is split off and the alcohol group immediately adjacent to it is oxidized to a carboxyl group. This phenomenon has prevented the determination, by purely chemical means, of the configuration of rhamnose at that carbon atom which is in the δ position to the aldehyde group.⁴³ Quite recently this problem has been solved by Hudson.⁵⁴

The hypothesis of Hudson may be stated briefly: The polyhydric alcohols and the sugar acids have feeble rotatory power, while the lactones of these acids as well as the sugars and the glucosides,—all of which contain lactonic rings,—possess strong rotatory power; hence the property of producing a considerable rotation of the plane of polarized light must be due to the presence of a lactonic ring. The configuration formulæ of twenty-

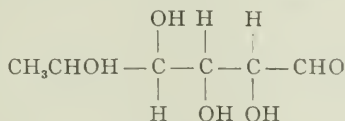
four acid lactones,—ranging from pentonic to nononic lactones,—have been derived by Fischer and his school; the rotatory power of each of these lactones has also been determined. Now if these configuration formulæ be written horizontally, it is seen that, in every case, the lactonic ring is above the chain when the lactone is laevorotatory and below the chain when the lactone is dextrorotatory, *e.g.*:



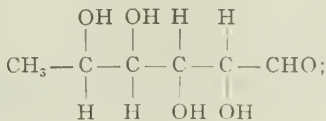
Methyl tetronic lactone has a specific rotation of -47° hence the lactonic ring must be above the chain. Therefore the configuration at that carbon atom which is in the γ position to the carboxyl group in methyl tetronic acid, and in the δ position to the aldehyde group in rhamnose, must be



Combining this fact with the partial configuration formula for rhamnose



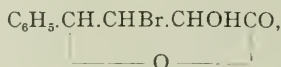
as determined by chemical means it follows that this sugar has the configuration



hence rhamnose is l-mannose, in which the terminal primary alcohol group has been reduced to a methyl group.

AN AROMATIC MONOSE.

Phenyl tetrose, an aromatic sugar, has been synthesized from cinnamic aldehyde by a rather complicated process.⁵⁵ Cinnamic aldehyde forms a cyanhydrin, which adds bromine at the double bond. This compound, when saponified by means of mineral acid, gives rise to the lactone of α - γ -dihydroxy- β -brom- γ -phenylbutyric acid,



which is converted into phenyltrioxybutyric acid by treatment with barium hydroxide. The lactone of the latter acid gives rise to phenyl tetrose upon reduction. The sugar thus produced is optically inactive by external compensation.

SYNTHESIS OF THE MONOSES FROM THEIR ELEMENTS.

Both formaldehyde and glycerol have been synthesized from their elements. Formaldehyde is condensed by lime water. From glycerol are derived glycerose and acrolein bromide; the former is condensed by sodium hydroxide; the latter is both saponified and condensed by baryta water. All these condensation products contain α -acrose (dl-fructose) which is isolated as its osazone and regenerated by the reduction of the osone.

Fermentation of dl-fructose gives l-fructose. dl-Fructose reduces to dl-mannite, which is oxidized through dl-mannose to dl-mannonic acid. This acid is split by means of its strychnine and morphine salts into d-mannonic acid and l-mannonic acid. d-Mannonic lactone reduces to d-mannose, which may give rise to phenyl d-glucosazone, d-glucosone and d-fructose. d-Mannonic acid is heated with quinoline to obtain d-gluconic acid, the lactone of which reduces to d-glucose. Upon oxidation d-glucose yields d-saccharic acid, which reduces to d-gulose. d-Gulonic acid gives rise to d-idonic acid when heated with aqueous pyridine under pressure, d-idonic lactone reduces to d-idose. In a similar manner it is possible to synthesize the four laevo aldohexoses of the mannite series,—l-mannose, l-glucose, l-gulose and l-idose,—from l-mannonic acid.

The three known aldohexoses of the dulcitate series may be synthesized from l-gulose. Calcium l-gulonate is oxidized by

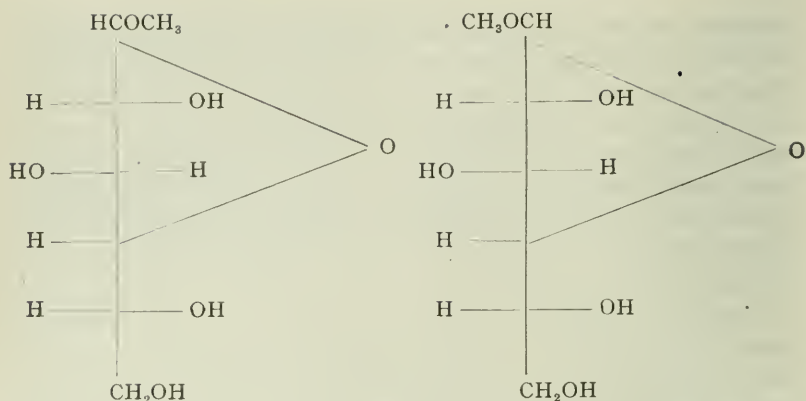
hydrogen peroxide in the presence of ferric acetate to l-xylose;⁴⁰ l-xylic acid is converted on heating with aqueous pyridine under pressure into d-lyxonic acid, the lactone of which reduces to d-lyxose. By the cyanhydrin synthesis, d-lyxose is transformed into d-galactonic acid and d-talonic acid; the lactones of these acids reduce to d-galactose and d-talose respectively. d-Galactose oxidizes to mucic acid, which yields dl-galactose on reduction; yeast ferments dl-galactose with the production of l-galactose.

Since the aldohexoses have been synthesized from their elements, the synthesis from the elements has also been achieved for the higher monoses, which have been built up from mannose, glucose and galactose, as well as for the pentoses, which have been obtained synthetically from the aldohexoses.

The diose, glycollaldehyde, is prepared from acetaldehyde and the triose, glycerose, from glycerol. Since both acetaldehyde and glycerol have been built up from their elements, both glycollaldehyde and glycerose have been synthesized from the elements.

THE GLUCOSIDES.

The synthetic glucosides are formed by the union of sugars and either alcohols or monohydric phenols with the elimination of water; they do not react with phenylhydrazine even at 100° C., and are readily hydrolyzed by boiling dilute acids.⁵⁶ On the other hand, when the solution of the α -hydroxyketone, benzoin, in methyl alcohol is treated with gaseous hydrogen chloride, a methyl benzoin, $C_6H_5.CO.CHOCH_3.C_6H_5$, is produced which reacts with phenylhydrazine even in the cold and which is far more resistant to the hydrolyzing action of hydrochloric acid than are the glucosides.⁵⁷ Hence the hydroxyl group at that carbon atom, which is in the α position to the aldehyde or ketone group of a sugar, takes no part in the glucoside-formation; therefore in all probability the hydroxyl group attached to the γ carbon atom enters into the reaction. Moreover, the carbon atom of the aldehyde or ketone group is rendered asymmetric by the formation of a glucoside; as a result whenever a sugar reacts with an alcohol to give rise to a glucoside, the latter exists in two forms,—the α and β varieties,—which differ in configuration only at that particular carbon atom. Thus from d-glucose and methyl alcohol are derived α -methyl d-glucoside and β -methyl d-glucoside.

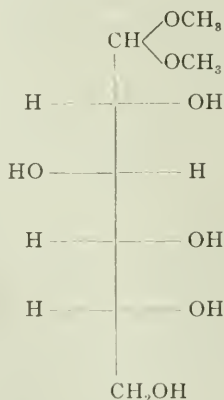


The Isomeric Methyl d-Glucosides

The α and β derivatives of the same sugar and the same alcohol differ in behavior toward enzymes and in physical properties like solubility, melting point and specific rotation.

Several methods have been devised for the preparation of synthetic glucosides. Thus the solution of a sugar in an alcohol is converted into a glucoside, if the cooled solution be saturated with gaseous hydrogen chloride.⁵⁶ This method may be used with the aldoses and with both aliphatic alcohols, and aromatic alcohols like benzyl alcohol.

If finely powdered d-glucose be shaken with a 1 per cent. solution of hydrogen chloride in methyl alcohol at room temperature, d-glucose dimethyl acetal is formed:⁵⁸

d-Glucose Dimethyl
Acetal

When the solution of the acetal in the dilute alcoholic hydrogen chloride is heated, the acetal splits off methyl alcohol and is partially converted into α - and β -methyl d-glucosides; each of the glucosides and the acetal are factors in the resulting equilibrium. The glucoside of any aldose and any alcohol may be prepared by dissolving the sugar in the alcohol, to which 1 per cent. or less of gaseous hydrogen chloride has been added, and then heating the solution under pressure at 100° C. The ketoses, —sorbitose and fructose,—may be converted into glucosides in the same manner, but the heating under pressure is omitted.⁵⁸

In another method for the preparation of glucosides,⁵⁹ the sugar is first changed into its acetyl derivative, which is then converted into an acetohalogen derivative. Thus d-glucose is transformed by boiling acetic anhydride into α -pentaacetylglucose in the presence of zinc chloride, and into β -pentaacetylglucose in the presence of sodium acetate; α - and β -pentaacetylglucose give rise respectively to α - and β -acetochloroglucose under the action of liquefied hydrogen chloride in a sealed tube at ordinary temperature; liquefied hydrogen bromide yields the corresponding acetobromoglucoses. If the solution of α -acetochloroglucose in methyl alcohol be shaken with silver carbonate at room temperature, tetracetyl α -methyl d-glucoside is formed; by subsequent saponification of the acetyl groups with barium hydroxide, α -methyl d-glucoside is obtained. In a similar way, β -acetochloroglucose yields tetracetyl β -methyl d-glucoside. In etherial solution both α - and β -acetochloroglucose react with sodium phenate to form tetracetyl β -phenol d-glucoside, from which β -phenol d-glucoside is obtained by the action of barium hydroxide. During the reaction between α -acetochloroglucose and sodium phenate, the α form is changed to the β isomer, hence α -phenol d-glucoside has never been prepared. This method may also be applied to certain disaccharides, thus octaacetyl maltose is converted by liquefied hydrogen chloride into β -acetochlormaltose; this compound reacts with methyl alcohol in the presence of silver carbonate to form heptaacetyl β -methyl maltoside, from which the acetyl groups are removed by means of barium hydroxide, in order to procure β -methyl maltoside.

Quite recently the glucosides of the camphors, menthol and borneol, have been synthesized.⁶⁰ Acetobromoglucose and menthol react in the presence of silver carbonate to form tetracetyl

β -menthol d-glucoside, from which β -menthol d-glucoside is obtained by the action of barium hydroxide. In a similar manner acetobromoglucose and d-borneol give rise to β -d-borneol d-glucoside. This method then is of the widest application, for it may be applied to monoses and disaccharides, to alcohols, phenols and camphors.

THE DISACCHARIDES.

Several disaccharides have been synthesized. The most widely applicable method for their synthesis depends upon the reaction between a monose and an acetohalogen-monose. Thus the alcoholic solution of β -acetochlorgalactose reacts at a low temperature with the aqueous solution of glucose in the presence of an alcoholic solution of sodium to form an acetylated galactosidoglucose, from which the sugar is liberated by the action of sodium hydroxide. Galactosidoglucose is probably identical with the natural disaccharide melibiose. In a similar manner, acetochlorgalactose and galactose give rise to galactosidogalactose, while acetochlorglucose and galactose react to form glucosidogalactose.⁶¹

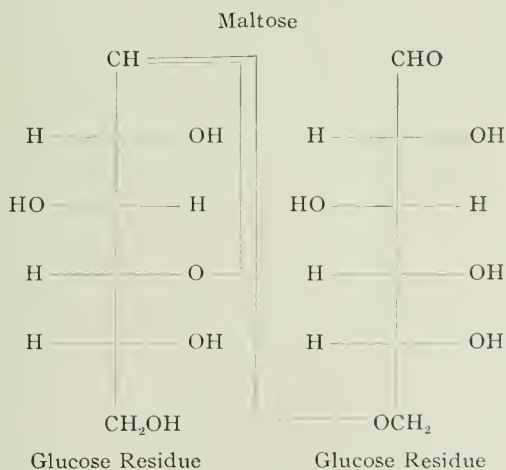
Isomaltose, a synthetic hexabiose, is a product of the action of concentrated hydrochloric acid upon glucose at a temperature of 10° to 15° C.⁶²

By means of enzymes⁶¹ several disaccharides have been synthesized, of which isolactose has received the most attention. Isolactose is formed by the union of glucose and galactose, with the elimination of water, under the influence of the enzyme lactase at a temperature of 35° C. This enzyme, which occurs in kefir-granules, is also able to produce a coupling of two glucose molecules with the formation of a hexabiose. In a similar way the enzyme emulsin causes the coupling of a glucose molecule and a galactose molecule.

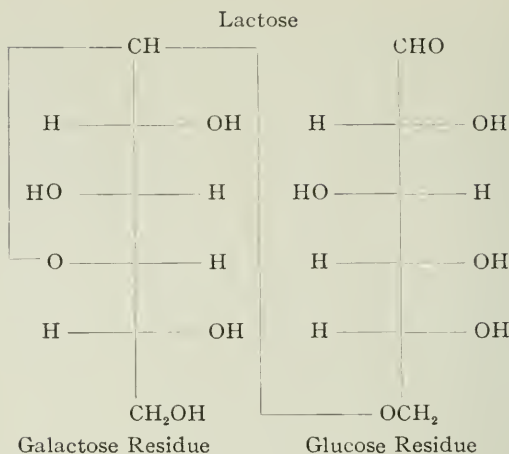
Bottom yeast causes fermentation of isolactose, galactosidoglucose and glucosidogalactose.⁶¹

The synthetic disaccharides all react with phenylhydrazine to form osazones, hence they all contain a free carbonyl group. Certain disaccharides like maltose and lactose resemble the synthetic disaccharides in the formation of osazones, and both the natural and synthetic disaccharides resemble the glucosides in their behavior toward inverting enzymes. Lactosone is hydro-

lyzed by 4 per cent. hydrochloric acid at the temperature of the water-bath into d-galactose and d-glucosone.⁶³ At room temperature, bromine oxidizes the aqueous solution of lactose to lactobionic acid, a monocarboxylic acid, which is converted into d-galactose and d-gluconic acid by the action of warm 5 per cent. sulphuric acid.⁶⁴ Through the cyanhydrin synthesis, lactose passes into a monocarboxylic acid, which contains thirteen carbon atoms and is known as lactosecarbonic acid;* this acid is split by warm 5 per cent. sulphuric acid into d-galactose and α -glucoheptonic acid.⁶⁵ These reactions show that the free carbonyl group of lactose must be contained in the glucose residue of that disaccharide. Maltosone is hydrolyzed by the inverting enzymes of yeast into d-glucose and d-glucosone.¹⁷ Maltobionic acid yields d-glucose and d-gluconic acid upon hydrolysis,⁶⁶ while maltosecarbonic acid * gives rise to d-glucose and α -glucoheptonic acid.⁶⁵ These reactions of the derivatives of lactose and maltose, as well as the behavior of the sugars themselves toward enzymes, are in harmony with the following formulæ, which also express the glucosidic nature of these disaccharides: ⁵⁶

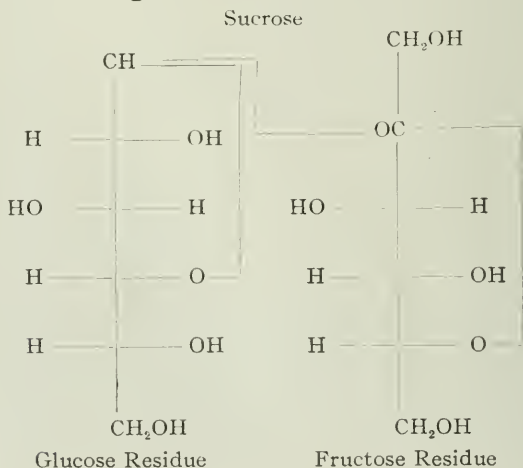


* On page vii, paragraph 93, of "Directions for Assistant Editors and Abstractors," accompanying Chemical Abstracts, 1910, IV, No. 12, the rule is given, "Names ending in -carbonsäure are to be translated -carboxylic acid." Under this nomenclature, lactosecarbonic acid and maltosecarbonic acid would be termed lactosecarboxylic acid, and maltosecarboxylic acid, respectively.



In that glucose residue, which contains the aldehyde group in both maltose and lactose, there is a possibility that, instead of the primary alcohol group, any one of the three secondary alcohol groups, occupying the β , γ or δ position to the aldehyde group, may take part in the anhydride formation. The fact that maltose and lactose give rise to osazones excludes from the anhydride formation that secondary alcohol group which is in the α position to the aldehyde group.

Since sucrose gives none of the reactions of the reducing sugars, the aldehyde group of the glucose residue and the ketone group of the fructose residue must both participate in the formation of glucosidic rings:



Several synthetic glucosido acids have been prepared. Thus, if the strongly concentrated, aqueous solution of d-glucose and d-gluconic acid be treated with gaseous hydrogen chloride, until the solution loses the power of reducing Fehling's solution, then the sugar and the acid have combined with the elimination of water to form glucosidogluconic acid.⁶⁷

ALCOHOLIC FERMENTATION OF THE SUGARS.

Only certain trioses, hexoses and nonoses are capable of undergoing alcoholic fermentation. In addition to the well-known examples, d-glucose, d-fructose and d-galactose, the following monoses are fermentable: glycerose,⁶⁸ d-mannose,⁶⁹ d-mannononose.¹¹ According to Buchner, alcoholic fermentation is due to the action of an endo-enzyme, zymase; this enzyme is secreted by the yeast cell, within which it remains during the life of the latter. The sugar passes by diffusion into the yeast cell and is there fermented by the enzyme. Zymase may be liberated from the yeast cell by grinding, with quartz sand, yeast which has been dried by compression, or by freezing yeast with solid carbon dioxide, then pulverizing the frozen mass. Buchner's work has been reviewed in a paper read before the Section by Dr. Bradbury.⁷⁰

Disaccharides are first inverted by the inverting enzymes; the resulting monoses then undergo alcoholic fermentation.

THE INVERTING ENZYMES.

In Nature are found four enzymes which exert an hydrolytic action upon the disaccharides and glucosides; they are invertin, maltase or glucase, lactase and emulsin. *Schizo-saccharomyces octosporus*, a yeast, secretes only maltase, while *Saccharomyces Marxianus*, another yeast, secretes only invertin.⁷¹ Certain yeasts, like Froberg yeast, secrete both invertin and maltase. Invertin is removed from the fresh yeast by water; however, maltase passes into solution only after the yeast has been ground with glass powder to rupture the cells, or after the yeast has been dried.⁷² Likewise, lactose-yeast contains two enzymes, invertin, which may be removed by water, and lactase, which passes into solution after the air-dried lactose-yeast has been ground with glass powder to rupture the cells; lactase is also found in

kefir granules.⁷² Emulsin, which occurs in the vegetable kingdom, *c.g.*, in almonds, was investigated by Liebig and Wöhler during their study of amygdalin and the oil of bitter almonds.⁴

Invertin inverts only sucrose.⁷³ Maltase produces hydrolysis of maltose and of certain α glucosides like α -methyl d-glucoside, α -methyl d-fructoside,⁷³ and α -ethyl d-glucoside,⁷⁴ therefore maltose belongs to the α series of glucosides. Emulsin splits lactose and certain β glucosides like β -methyl d-glucoside, β -phenyl d-glucoside,⁷⁴ β -methyl d-galactoside⁵⁸ and β -phenyl d-galactoside,⁷⁵ as well as many natural glucosides, *c.g.*, salicin, coniferin, arbutin, esculin, etc.;⁷⁶ hence lactose and the natural glucosides apparently belong to the β series. Lactase causes hydrolysis of lactose⁷² and of β -methyl, β -ethyl and β -phenyl d-galactosides;⁷⁷ it differs from emulsin by not acting upon β -methyl d-glucoside or amygdalin.⁷²

A glucoside, which is derived from a disaccharide, may be hydrolyzed by both maltase and emulsin, but with the formation of different products. Thus β -methyl maltoside is converted into maltose and methyl alcohol by emulsin, while it is changed into d-glucose and β -methyl d-glucoside by maltase.⁷⁸ Under the influence of emulsin, amygdalin gives rise to benzaldehyde, prussic acid and a fermentable sugar (d-glucose);⁴ maltase, however, changes amygdalin into d-glucose and mandelonitrile glucoside.⁷⁹ Emulsin decomposes the latter with the formation of d-glucose, benzaldehyde and hydrocyanic acid.⁷⁹

Of the synthetic disaccharides, galactosidoglucose, glucosidogalactose and galactosidogalactose are hydrolyzed by emulsin, while isolactose is inverted by kefir-lactase.⁶¹

The inverting enzymes do not act upon the glucosides of sugars which have a *lævo* configuration, for instance, maltase does not produce hydrolysis of α -methyl l-glucoside.⁷⁴

Inverting enzymes are found in various animal secretions and organs.⁸⁰

THE LOCK AND KEY THEORY OF ENZYME ACTION.

Fischer and Thierfelder⁸¹ found that, when yeasts in pure culture were permitted to act upon nine different aldohexoses, fermentation occurred with only three of the sugars, d-glucose, d-mannose and d-galactose. Under the same conditions, of

the ketohexoses, d-fructose, l-fructose and sorbose, only d-fructose was fermented. Now d-glucose, d-mannose, d-fructose and d-galactose differ but slightly in configuration; when a yeast ferments these sugars and leaves the other hexoses unchanged, its choice is not for one of two optical antipodes, but is entirely dependent upon the configuration. Fischer and Thierfelder explain the phenomenon: "Among the agents, of which the living cell makes use, the different proteins play the leading rôle. They are likewise optically active, and, since they arise synthetically from the carbohydrates of the plants, one may indeed assume that the geometric structure of their molecules, in respect to asymmetry, is essentially similar to that of the natural hexoses. With this acceptance, it should not be difficult to understand that the yeast cells with their asymmetrically formed agent can attack and act with the production of fermentation only upon those sugars, of which the geometric structure does not differ too widely from that of glucose."

Fischer extended this theory to include the inverting enzymes. "As is well known invertin and emulsin bear many an analogy to the proteins and, like the latter, undoubtedly possess an asymmetrically constructed molecule. Their limited action upon the glucosides therefore may be explained by the hypothesis that that approach of the molecules, which is essential for the occurrence of chemical reaction, can take place only in case of similar geometric structure. To use a comparison, I will say that enzyme and glucoside must fit each other like lock and key in order to be able to exert a chemical action upon each other."⁷⁴

"If one wishes to do justice to the fact that some yeasts can ferment a greater number of hexoses than others, then the comparison may be completed by the distinction of master key and special key."²⁰

Saccharomyces productivus ferments d-mannose and d-fructose but has no action upon d-galactose, while *Saccharomyces cerevisia* I produces fermentation of all three of these sugars.⁸¹ Now it may be considered that *Saccharomyces productivus* secretes a zymase which is a special key for d-mannose and d-fructose, while *Saccharomyces cerevisia* I secretes a zymase, which is a master key and acts upon not only d-mannose and d-fructose but also d-galactose.

THE SPLITTING OF RACEMIC COMPOUNDS INTO THEIR
ACTIVE CONSTITUENTS.

For the separation of racemic compounds into their active constituents, Pasteur⁸² introduced three methods: fermentation, simple crystallization, and the difference in solubility of the salts of the two optical antipodes with one and the same optically active compound. Fischer has utilized all these methods in splitting the racemic compounds of the sugars into their active constituents, and has added to them a fourth method—the action of enzymes.

When beer yeast acts upon the aqueous solution of any one of the racemic hexoses,—dl-mannose,⁹ dl-fructose,⁹ dl-glucose,³⁸ dl-galactose,⁴²—it ferments the dextro antipode, and thus a solution is produced which contains only the hexose of laevo configuration. The separation of racemic compounds of the sugar group into their active constituents by means of fermentation with *Penicillium glaucum* is incomplete and therefore unsatisfactory. The action of this mould upon dl-mannonic acid and upon dl-fructose has been studied.⁹

Under suitable conditions the solution of a racemic compound will deposit crystals of the two optical antipodes, which are distinguished from each other as right-handed and left-handed crystals by means of their hemihedral faces and thus may be separated mechanically. For instance, the solution of dl-gulonic lactone deposits crystals of d-gulonic lactone and of l-gulonic lactone, which may be separated mechanically.⁸³ The solution of methyl dl-mannoside deposits crystals of methyl d-mannoside and methyl l-mannoside at temperatures between $+2^{\circ}$ and $+8^{\circ}$ C.; the crystals may be separated mechanically. At temperatures above $+15^{\circ}$ C., crystallization of methyl dl-mannoside, the racemic compound, occurs.⁸⁴

If the strychnine salt of dl-mannonic acid be dissolved in hot absolute alcohol, strychnine l-mannonate crystallizes out in a few moments at the boiling temperature; the mother liquor contains the d-mannonate of the alkaloid and some of the salt of the laevo acid. The d-mannonic acid is finally isolated from the mother liquor as the morphine salt.⁹

When emulsin acts upon a racemic mixture of β -methyl d-glucoside and β -methyl l-glucoside, the β -methyl d-glucoside is

hydrolyzed by the enzyme while β -methyl l-glucoside, the optical antipode, remains unchanged. In a similar way, the yeast enzyme, maltase, acts upon α -methyl dl-glucoside, producing hydrolysis of α -methyl d-glucoside but failing to act upon α -methyl l-glucoside.⁸⁵

ASYMMETRIC SYNTHESIS.

Whenever compounds, which do not contain an asymmetric carbon atom, react to form a compound containing such an atom, the two stereoisomers are formed in equal quantities, and the new compound is racemic, *i.e.*, optically inactive by external compensation. Thus acetaldehyde adds prussic acid to form dl-lactonitrile, which is saponified by mineral acids with the production of dl-lactic acid.

However, if one of the reacting compounds be optically active, the reaction proceeds asymmetrically, *i.e.*, the two new compounds are formed in unequal quantities. α -Glucoheptose by the cyanhydrin synthesis gives rise to two octoic acids, α -glucooctoic acid and β -glucooctoic acid. If the addition of hydrocyanic acid occur at 20° to 25° C., the yield of α acid amounts to 73 per cent. of the theoretical yield of octoic acid, and the β acid is almost entirely absent from the product; when the reaction is carried out at 40° C., the quantity of β acid equals 13 per cent. of the theoretical amount of octoic acid, but the α acid still forms by far the greater part of the product.¹⁰

By the cyanhydrin synthesis, d-mannose gives rise to but one d-mannoheptoic acid; the theoretically possible isomer is not present in the mother liquor. The yield of d-mannoheptoic acid is 87.4 per cent. of the theoretical yield of heptoic acid. A study of the salts of d-mannoheptoic acid with metals and with alkaloïds has shown the unitary nature of this acid.⁸⁶ Therefore this synthesis is wholly asymmetric.

Glucoside formation may occur asymmetrically. Thus methyl alcohol and d-mannose unite in the presence of 0.25 per cent. hydrogen chloride to form methyl d-mannoside; the theoretically possible isomer is not present in the mother liquor.⁸⁴ This reaction is entirely asymmetric.

It is possible to proceed from a compound containing an optically active group, and to build from this compound a second compound which will contain a new asymmetric carbon atom—the product of synthesis. The reaction proceeds in an asym-

metric way, and, after the original active group has been eliminated from the new compound, the final synthetic product will be optically active. For example, helicin (salicylic aldehyde glucoside) contains an optically active glucose group, and also forms a tetracetyl derivative. This derivative adds prussic acid to give rise to a cyanhydrin—origin of the new asymmetric carbon atom. Liquefied hydrogen chloride, in the presence of the theoretic quantity of water, saponifies the cyanhydrin to the amide of tetracetylgluco-o-oxy mandelic acid. The latter compound is converted into o-oxy mandelic acid by warm dilute hydrochloric acid—removal of the original active group. The o-oxy mandelic acid has a slight dextro rotation, but unfortunately has not been obtained crystalline.⁸⁷

The formation of sugar from the carbon dioxide of the air in the presence of sunlight by the chlorophyll of plants is an example of asymmetric synthesis. According to Fischer, the optically active chlorophyll first combines with either carbon dioxide or its reduction product, formaldehyde. The condensation to sugar which then occurs, is influenced by the asymmetry of the chlorophyll molecule and proceeds asymmetrically. Next the sugar is liberated from the complex molecule and exists as an optically active compound by virtue of its asymmetric synthesis.²⁰

Liebig and Wöhler begin the description of their classic research upon the radical of benzoic acid⁸⁸ with the following statement. Whenever, in the dark realm of organic Nature, one succeeds in finding a luminous point, which appears to us as one of the entrances by means of which we may possibly come to the right road for the investigation and recognition of this realm, then one has reason to congratulate himself, even if he be aware of the fact that the realm in question is inexhaustible.

Fischer has illumined for us three great divisions of the realm of organic chemistry, the purin bases, the amino acids, polypeptides and proteins, and the carbohydrates and their ferments.

REFERENCES.

¹ Fischer: Die Chemie der Kohlenhydrate und ihre Bedeutung für die Physiologie. Rede, gehalten zur Feier des Stiftungstages der militärärztlichen Bildungsanstalten am 2 August 1894. Untersuchungen über Kohlenhydrate und Fermente, 96.

² Bradbury: JOURNAL OF THE FRANKLIN INSTITUTE, 1909, clxviii, 85.

- ³ Chemical Essays of Charles William Scheele. Translated by Beddoes. Murray, London 1786. Re-issued by Scott, Greenwood and Co., London 1901. Essay xviii, On the Acid of Saccharum Lactis.
- ⁴ Liebig and Wöhler: Liebig's Annalen, 1837, xxii, 1.
- ⁵ Fischer: Berichte der deutschen chemischen Gesellschaft, 1890, xxiii, 2114; 1894, xxvii, 3189; 1907, xl, 102.
- ⁶ Untersuchungen über Kohlenhydrate und Fermente 1884-1908, von Emil Fischer, Berlin. Verlag von Julius Springer, 1909, 896.
- ⁷ Fischer: Berichte, 1884, xvii, 579; 1887, xx, 821.
- ⁸ Fischer and Hirschberger: Berichte, 1888, xxi, 1805.
- ⁹ Fischer: Berichte, 1890, xxiii, 370.
- ¹⁰ Fischer: Liebig's Annalen der Chemie, 1892, cclxx, 64.
- ¹¹ Fischer and Passmore: Berichte, 1890, xxiii, 2226.
- ¹² Fischer: Liebig's Annalen der Chemie, 1895, cclxxxviii, 139.
- ¹³ Smith: Liebig's Annalen der Chemie, 1892, cclxxii, 182.
- ¹⁴ Fischer and Piloty: Berichte, 1890, xxiii, 3102.
- ¹⁵ Fischer: Berichte, 1891, xxiv, 3622.
- ¹⁶ Fischer: Berichte, 1888, xxi, 2631; 1889, xxii, 87.
- ¹⁷ Fischer and Armstrong: Berichte, 1902, xxxv, 3141.
- ¹⁸ Fischer: Berichte, 1889, xxii, 94.
- ¹⁹ Fischer: Berichte, 1890, xxiii, 3684.
- ²⁰ Fischer: Berichte, 1894, xxvii, 3189.
- ²¹ Fischer and Hirschberger: Berichte, 1889, xxii, 365.
- ²² Fischer and Tafel: Berichte, 1887, xx, 3384.
- ²³ Fischer and Tafel: Berichte, 1888, xxi, 2634; 1889, xxii, 106.
- ²⁴ Fischer and Hirschberger: Berichte, 1889, xxii, 3218.
- ²⁵ Fischer: Berichte, 1891, xxiv, 539.
- ²⁶ Fischer: Berichte, 1889, xxii, 2204; 1890, xxiii, 930.
- ²⁷ Fischer and Piloty: Berichte, 1891, xxiv, 521.
- ²⁸ Fischer: Berichte, 1890, xxiii, 799.
- ²⁹ Fischer: Berichte, 1891, xxiv, 2136.
- ³⁰ Fischer and Piloty: Berichte, 1891, xxiv, 4214.
- ³¹ Fischer and Bromberg: Berichte, 1896, xxix, 581.
- ³² Kiliani: Berichte, 1885, xviii, 3066; 1886, xix, 221, 767, 1128.
- ³³ Fischer and Passmore: Berichte, 1890, xxiii, 2226.
- ³⁴ Ruff: Berichte, 1898, xxxi, 1573; 1899, xxxii, 550.
- ³⁵ Tollens and Gans: Berichte, 1888, xxi, 2150; Liebig's Annalen der Chemie, 1888, ccxlix, 256.
- ³⁶ Reiss: Berichte, 1889, xxii, 609. Fischer and Hirschberger: Berichte, 1889, xxii, 1155, 3218.
- ³⁷ Fischer and Fay: Berichte, 1895, xxviii, 1975.
- ³⁸ Fischer: Berichte, 1890, xxiii, 2611.
- ³⁹ Fischer and Stahel: Berichte, 1891, xxiv, 528.
- ⁴⁰ Fischer and Ruff: Berichte, 1900, xxxiii, 2142.
- ⁴¹ Fischer: Berichte, 1890, xxiii, 930.
- ⁴² Fischer and Hertz: Berichte, 1892, xxv, 1247.
- ⁴³ Fischer and Morrell: Berichte, 1894, xxvii, 382.
- ⁴⁴ Fischer and Tafel: Berichte, 1887, xx, 1088. Fischer: Berichte, 1894, xxvii, 3189.
- ⁴⁵ Fischer and Tafel: Berichte, 1887, xx, 1088, 3384; 1888, xxi, 2634.
- ⁴⁶ Fischer and Tafel: Berichte, 1887, xx, 2566.
- ⁴⁷ Fischer and Passmore: Berichte, 1889, xxii, 359.
- ⁴⁸ Fischer and Landsteiner: Berichte, 1892, xxv, 2549.
- ⁴⁹ Fischer: Berichte, 1895, xxviii, 1973.
- ⁵⁰ Fischer and Tafel: Berichte, 1887, xx, 1088; 1888, xxi, 1657, 2173.
- ⁵¹ Fischer and Liebermann: Berichte, 1893, xxvi, 2415.
- ⁵² Fischer: Berichte, 1896, xxix, 1377.
- ⁵³ Fischer and Herborn: Berichte, 1896, xxix, 1961.
- ⁵⁴ Hudson: United States Department of Agriculture, Bureau of Chemistry, Circular No. 49, 1910; Journal of the American Chemical Society, 1910, xxxii, 338.

- ⁵⁵ Fischer and Stewart: Berichte, 1892, xxv, 2555.
- ⁵⁶ Fischer: Berichte, 1893, xxvi, 2400.
- ⁵⁷ Fischer: Berichte, 1893, xxvi, 2412.
- ⁵⁸ Fischer: Berichte, 1895, xxviii, 1145.
- ⁵⁹ Fischer and Armstrong: Berichte, 1901, xxxiv, 2885; 1902, xxxv, 833, 3153.
- ⁶⁰ Fischer and Raske: Berichte, 1909, xlii, 1465.
- ⁶¹ Fischer and Armstrong: Berichte, 1902, xxxv, 3144.
- ⁶² Fischer: Berichte, 1890, xxiii, 3687; 1895, xxviii, 3024.
- ⁶³ Fischer: Berichte, 1888, xxi, 2631.
- ⁶⁴ Fischer and Meyer: Berichte, 1889, xxii, 361.
- ⁶⁵ Reinbrecht: Liebig's Annalen der Chemie, 1892, cclxxii, 197.
- ⁶⁶ Fischer and Meyer: Berichte, 1889, xxii, 1941.
- ⁶⁷ Fischer and Beensch: Berichte, 1894, xxvii, 2478.
- ⁶⁸ Fischer and Tafel: Berichte, 1889, xxii, 106.
- ⁶⁹ Fischer and Hirschberger: Berichte, 1888, xxi, 1805; 1889, xxii, 3218.
- ⁷⁰ Bradbury: JOURNAL OF THE FRANKLIN INSTITUTE, 1904, clvii, 41.
- ⁷¹ Fischer and Lindner: Berichte, 1895, xxviii, 984.
- ⁷² Fischer: Berichte, 1894, xxvii, 3479.
- ⁷³ Fischer: Berichte, 1894, xxvii, 3479; 1895, xxviii, 1420.
- ⁷⁴ Fischer: Berichte, 1894, xxvii, 2985.
- ⁷⁵ Fischer and Armstrong: Berichte, 1902, xxxv, 833.
- ⁷⁶ Fischer: Berichte, 1894, xxvii, 2985; Zeitschrift für physiologische Chemie, 1898, xxvi, 60.
- ⁷⁷ Fischer and Armstrong: Berichte, 1902, xxxv, 3153.
- ⁷⁸ Fischer and Armstrong: Berichte, 1901, xxxiv, 2885.
- ⁷⁹ Fischer: Berichte, 1895, xxviii, 1508.
- ⁸⁰ Fischer and Niebel: Sitzungsberichte der Königlich preussischen Akademie der Wissenschaften zu Berlin, 1896, v 73.
- ⁸¹ Fischer and Thierfelder: Berichte, 1894, xxvii, 2031.
- ⁸² Pasteur: Researches on the Molecular Asymmetry of Natural Organic Products, 1860: Alembic Club Reprints, No. 14.
- ⁸³ Fischer and Curtiss: Berichte, 1892, xxv, 1025.
- ⁸⁴ Fischer and Beensch: Berichte, 1896, xxix, 2927.
- ⁸⁵ Fischer: Berichte, 1899, xxxii, 3617.
- ⁸⁶ Hartmann: Liebig's Annalen der Chemie, 1892, cclxxii, 190.
- ⁸⁷ Fischer and Slimmer: Berichte, 1903, xxxvi, 2575.
- ⁸⁸ Liebig and Wöhler: Annalen der Pharmacie, 1832, iii, 249.

THE EFFECT OF CRYSTALLINE PIGMENTS ON THE PROTECTION OF WOOD.

BY

HENRY A. GARDNER.

[The writer has made a study of paint tests upon different grades and kinds of wood, and has been impressed with the uniformly bad results obtained when the wood is not properly selected.]

It makes little difference what paint is tested when faulty wood is used, for the result in every case will be failure. A notable instance of such failure is recorded in the tests conducted at Fargo, North Dakota, by the Agricultural Experiment Station and the Paint Manufacturers' Association, where most of the wood used on the western side of the test fences (northern hard pitch pine) was extremely sappy and of a hard grain. After a few months' wear, the resinous sap, through the action of the sun, pushed itself through the paint and completely obliterated the latter in many spots. Again, at Atlantic City and at Pittsburgh, in the paint tests ¹ made under the inspection of the American Society for Testing Materials and the direction of the Carnegie Technical Schools, it developed that cypress and yellow pine gave unsatisfactory results in many cases. The inspectors, therefore, were forced to draw their conclusions from these tests almost universally from the white pine panels. Paint tests, therefore, if their object is to determine the value of pigments, should be made upon high grade wood, such as white pine or poplar carefully inspected and seasoned.

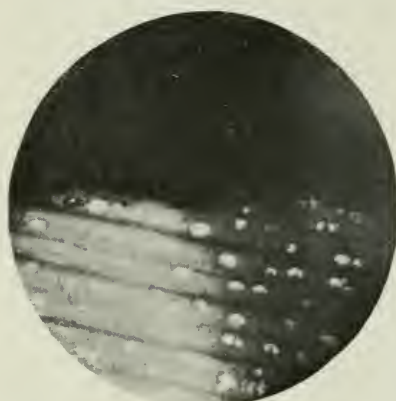
Seasoning and Drying.—The importance of the proper seasoning and drying of wood cannot be overestimated, as the effect of an excess of moisture in lumber is bad from every standpoint. Every one is familiar with the appearance of a

¹ In these tests, over one thousand panels of different grades of wood were painted with different pigments, alone and in combination, and in several colors. A full report of the wearing of each formula on these tests may be had by writing to the Scientific Section, Paint Manufacturers' Association, 3500 Gray's Ferry Road, Philadelphia, for Bulletins 16, 17, 25, 26, and 28.

building painted immediately upon erection in the early spring, when the excess moisture in the wood, or the moisture that comes from the plaster, works itself to the surface. The badly stained appearance of the paint, which first indicates that moisture is working through, is followed by scaling and blistering, and the effort to beautify and protect has been defeated.

The strength of wood is also vitally affected by the moisture content. It is fairly well known that the strength begins to be greatest when the excess moisture in the cells or honeycomb part of the wood is removed, and when that point is reached where the fibres or cell walls are satisfied. Kiln drying may remove

FIG. 1.



Maple (transverse section; one-half painted with lead and zinc paint containing 10 per cent. barytes and asbestine).

FIG. 2.



Maple (transverse section; one-half coated with white lead).

even more of this moisture, but if the moisture does not extend beyond the fibre saturation point, a fair degree of safety and strength is to be depended upon.

Action of Crystalline Pigments.—The effect of certain crystalline pigments in aiding the opaque white pigments in their battle to properly protect wood has been demonstrated in practice, and by test, and to-day the paint manufacturer is using these crystalline pigments in small percentage for this purpose. The filling of wood, such as floors for instance, has almost always been done by the use of pigments such as quartz silica, or very fine barium sulphate. The action of these pigments in penetrating the pores of the wood and becoming attached by

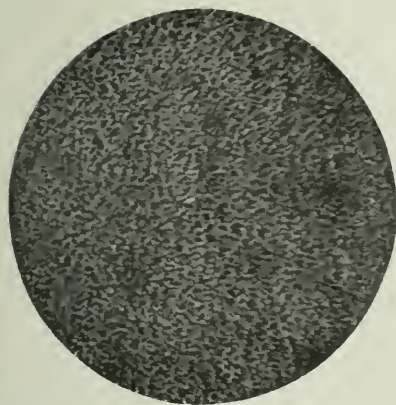
their rough surfaces, to the tentacles of the wood, is extremely important. Pigments such as zinc oxide or white lead are made up of particles more spherical and with smoother surfaces, and will not secure that same hold upon the woody fibre, obtainable

FIG. 3.



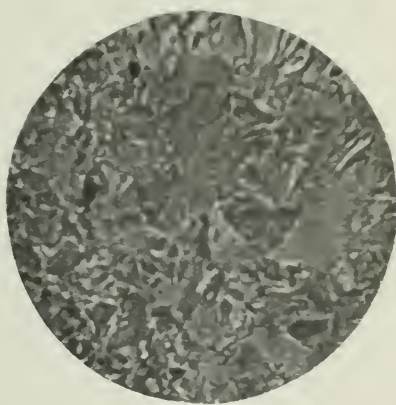
Asbestine; magnification 930.

FIG. 4.



Precipitated barium sulphate; magnification 930.

FIG. 5.



Silica.

through the use of the rougher or more crystalline pigments. The painter often uses materials such as yellow ochre for the priming coat for wood, understanding that the ochre has a high content of crystalline pigments, such as silica or silicates. It has been found, however, that a much better practice is to have the priming coat of a paint made up with a small percentage

of the pure crystalline pigments. The photomicrographs (Figs. 1 and 2) show the effect of painting one coat of a paint made up on the above basis, with crystalline pigments, as against the effect of using a single pigment paint. The wood used for this test,

FIG. 6.



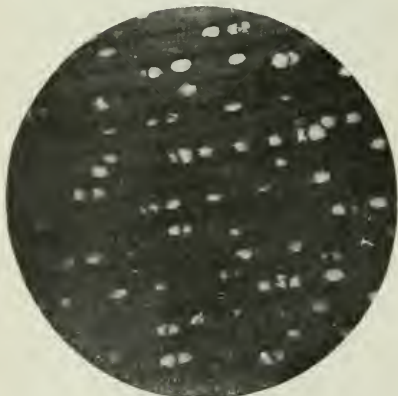
Hickory (transverse section).

FIG. 7.



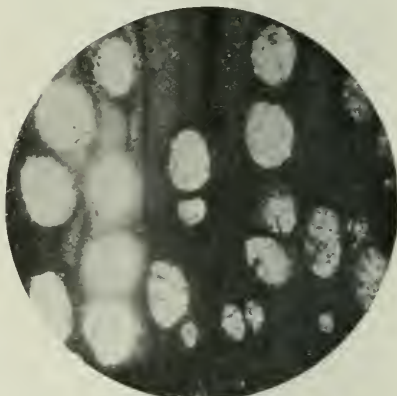
Red cedar (transverse section).

FIG. 8.



Maple (transverse section).

FIG. 9.



Locust (transverse section).

maple, is not one commonly used for exterior purposes, but its fibre offers even more resistance to a paint than the ordinary woods used in the building of houses. It can be seen, however, from the photomicrographs that excellent penetration and filling of the cells has been obtained. Figs. 3, 4, and 5 show magnified views of some of the crystalline pigments in their dry condition.

The Treatment of Refractory Woods.—Yellow pine, cypress and other hard woods used in the construction of frame buildings, generally contain a large quantity of pitch and sap which tend to harden the grain and make penetration of the paint almost impossible. To meet such conditions, the painter generally reduces the paste or liquid paint with turpentine or other volatile

FIG. 10.



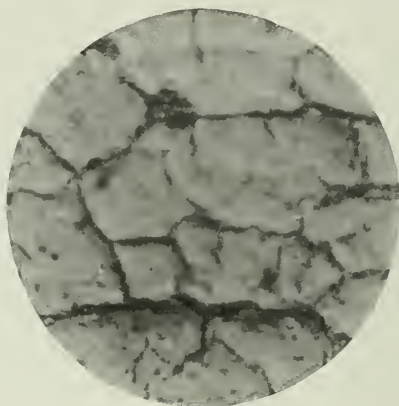
Gardner's photomicroscope in place for field work.

solvents that will act as accelerators in carrying the paint into the fibre of the wood, and even assist in amalgamating the paint with the resins contained in the wood. The use of new solvents, such as benzol, xylol, and toluol, to replace turpentine, is being experimented with, and so far very good results have been obtained. The penetrative values of the above-mentioned coal-tar distillates are high, and their price, as compared with the

price of turpentine, will probably make them commercially acceptable. Figs. 6, 7, 8, and 9 show transverse sections of a few American woods. Magnification, 56.

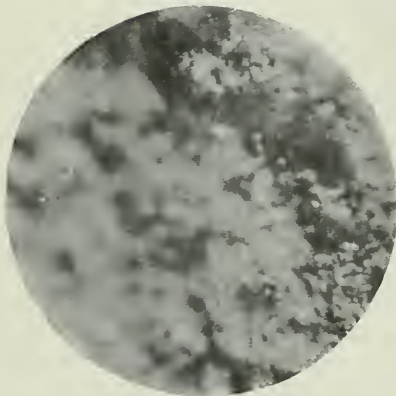
The Photomicroscope as an Adjunct in Field Inspections.—

FIG. 11.



Photomicrograph of surface painted with white lead showing checking present.

FIG. 12.



Photomicrograph of a concrete wall.

FIG. 13.



Photomicrograph of a piece of steel showing rust developing on surface.

The paint chemist is often called upon to report upon the value of a paint that has suffered exposure. The conditions generally looked for as being indicative of the value of a paint are hiding power, gloss, color maintenance, degree of chalking, general condition, and checking. Most of these conditions are easily

determined, except the latter, which cannot always be seen by the naked eye. A great many paints soon after exposure become very hard and brittle, and fine checking starts in. In order to determine the amount of checking present, and permanently record the condition, the writer has developed an apparatus which has given most satisfactory results. Its value in the field, to the paint inspector, cannot be overestimated. The apparatus (Fig. 10) is made in the following manner:

The arm and body of a microscope containing a draw tube fitted with objective and eyepiece is mounted in a horizontal position on a solid iron base, the bottom of which is punched and threaded to the standard size to receive the screw from the top of a heavy tripod. This latter piece of apparatus is placed close to the painted surface, and, by raising or lowering the tripod, the microscope can be placed in front of any spot it is desired to inspect. By regulating the coarse adjustment, the microscope is focused on the painted surface in such a way that any checking, cracking, paint coat abrasions, or other disturbing influences, even of the slightest degree, are promptly brought to the eye of the observer. The tube-camera apparatus is then placed directly over the eyepiece of the microscope and exposure is made by lifting the shutter-cap for twenty or thirty seconds, according to light conditions, giving an excellent detail photograph.

The tube camera is made of a metal tube $1\frac{1}{2}$ inches in diameter, into which is placed a lens and shutter fixed to the ordinary bulb apparatus for making an exposure. On the rear end of this tube is placed a disk of metal into which is fitted a block of wood having a central annular opening the size of the tube. On the back of the block is firmly set and screwed into position a film pack, such as is used for the ordinary photographic camera.

Figs. 11, 12, and 13 show photomicrographs made with this apparatus.

EXPLOSIVES.

BY

F. H. GUNSOLUS,

Manager, Technical Division, E. I. du Pont de Nemours Powder Co., Wilmington, Del.

THIS subject of *Explosives* is one in which we are all rightly and justly interested and one which the majority of consumers are to-day studying as hard and thoroughly as the manufacturer, both from a humanitarian and economic standpoint; or first, to produce the safest for use, at the same time protecting the lives of the users, and second, to supply the best at minimum cost. The consumer is making it a study with the idea of determining what kind of explosive and which explosive is better adapted for the work in hand. The manufacturer studies the subject with the idea of supplying that explosive which will fill the various conditions and demands not only for the present time but also future demands.

From the time of the invention of gunpowder, or approximately in 1250, the study of explosives has been the problem for generations. With the new kinds of High Explosives, "Permissible" Explosives, Sporting Powders and Detonating Agents, the problem is one of greater moment and continues to be studied with increased care, and by a larger number of expert chemists. Perhaps a short historical retrospect will be very useful in order to fully appreciate this fact.

Gunpowder was known in a crude form by the Chinese for many centuries, but the earliest date of which there is record and which can be considered authentic in any way is 1264, when Roger Bacon made known the results of his tests. I believe, however, that the Western World only used this gunpowder for throwing projectiles. Not until 1629 was gunpowder used as a blasting agent, at which time Casper Weindl invented the use of gunpowder for blasting purposes. A demonstration was made at Schemnitz in Hungary, where it was shown conclusively that its use would materially aid in mining and quarrying operations. Until the beginning of the Nineteenth Century, however, no other explosive was introduced into practice with success. In

1788 Bertholet and Lavoisier tried the effect of adding potassium chlorate, and in 1861 Designolle made a powder from potassium picrate and saltpetre but without much success. In 1846 Schoenbein invented gun-cotton and in 1847 Sobero discovered nitroglycerin. The Austrian Government, which was the only one to try gun-cotton in guns, stopped the experiment abruptly in 1867, due to their having an explosion in the magazines at Hirtenberg. Not until 1863 was nitroglycerin available for general use owing to its extreme sensitiveness and to the inconvenience of handling it in its liquid state. Alfred Nobel, the great Swedish chemist, at this time found by using infusorial earth, known as Kieselguhr, as an absorbent for the nitroglycerin, it would overcome these objections to a large extent, and in 1867 he introduced this mixture under the name of dynamite. About this time the success of dynamite was assured by the discovery of the detonating effect of fulminate of mercury in the dynamite by Brown, a chemist in the English War Office. Gelatin dynamite was next produced when Alfred Nobel discovered that nitro-cotton was easily dissolved in nitroglycerin, forming an explosive gelatinous mass which he called blasting gelatin.

Such was practically the state of affairs as concerns explosives up to the year 1886. About this time it was recognized that most explosions in coal mines were due to the ignition of fire-damp by the firing of shots, and it was also recognized that it would be possible to produce explosives which could be used in coal mines and which would considerably reduce this danger.

From 1886 the strides made in the investigations, inventions and productions of different kinds of explosives have been very rapid. In fact, all explosive manufacturers produce two or three of the following kinds of explosives: Straight Nitroglycerin Dynamites, Gelatin Dynamites, Ammonia Dynamites, "Permissible" Explosives, Low-freezing Dynamites, Non-freezing Dynamites and Detonators of different varieties. It is left, however, to the largest manufacturers of explosives to produce all of the different kinds just mentioned.

According to the Standard Dictionary, "an explosive is any substance that may cause an explosion by its sudden combustion or decomposition." A distinction, however, should be made be-

tween explosives in general and those which are applicable to blasting purposes: a mixture of oxygen and hydrogen gases, or of fire-damp and air, or coal dust, or flour dust and air, etc., may be termed explosive, as when mixed in the proper proportion they may be exploded by a spark, flame, or by having the temperature raised by any other means.

Another very good definition of an explosive is, "Such a substance as can in an extremely short time and in a small space develop a very large amount of heat and gas exerting enormous pressure on the surrounding bodies, and is able by the expansion of highly heated gases to perform considerable work."

Some of the important qualifications of an explosive for blasting purposes are the following:

1. Sufficient stability.
2. Difficulty of detonation by mechanical shock, that is, not too sensitive.
3. Handy form.
4. Absence of injurious effect on the health of those using it.
5. Sufficient strength of action.
6. Sufficient density.
7. Comparative "flamelessness" and low heat of detonation for coal mining.

Explosives may be divided into two general classes:

1. *Low* explosives or direct exploding materials, such as blasting powder.
2. *High* explosives or indirect exploding materials, such as dynamite, gun-cotton, gelatin dynamite, ammonium nitrate, picric acid, etc.

By direct exploding materials are meant those which can be made to develop their force by direct means, such as ignition; whereas the indirect exploding materials require an intermediate agent to develop their full force, such as a blasting cap or electric fuze.

In the case of a low explosive, such as blasting powder, the force is developed by first burning some of the powder, the fire being transmitted from grain to grain, a certain amount of pressure and heat are developed, when the whole amount of powder is brought into sudden decomposition. This fact is readily shown by burning a small quantity of blasting powder unconfined, and then burning it confined, the pressure being an

important factor in bringing about the explosion of blasting powder. The finer the grain of the powder the greater proportionately is the amount of burning surface, and consequently, the quicker the complete transformation of the solid into the gases.

To the high explosive class belong all those explosives commonly known as dynamite, and which or may not have nitroglycerin as the explosive basis of the substances, such as: ordinary nitroglycerin dynamite, the ammonium-nitroglycerin compounds, gelatin dynamite, low-freezing dynamite, and the Judson powders. To this class belong all of the "Permissible" Explosives.

Whereas a perfect explosion of a low explosive results from burning, a perfect explosion of a high explosive is the result of the detonation of the explosive. This may be considered the result of a certain kind of shock causing the instantaneous destruction of the very delicately balanced forces which preserve the chemical and physical equilibrium of the explosive compound.

Defective blasting caps and electric fuzes are often causes of imperfect explosions of high explosives. Another cause, and one of frequent occurrence, is where dynamite is loaded in the same bore-hole with blasting powder without a detonator, the blasting powder being fired by the use of a squib or safety fuse. Another cause is where the fuse is laced through the cartridges of dynamite, which is very apt to set the dynamite on fire.

Before the sale of an explosive is undertaken those who manufacture and sell explosives should make such tests as will determine the characteristics of that particular explosive. Some of these points to be determined about any explosive are:

1. Sensitiveness.
2. Comparative strength.
3. Waterproof qualities.
4. Effects of temperature on the explosive.
5. Nature of gases resulting from detonation.
6. Velocity of detonation—that is *quickness*.
7. Height and duration of flame.
8. Temperature of detonation.
9. Heat of detonation.

There are many tests which have been devised and have been and are used to determine these various characteristics of

explosives as far as is possible before the explosive is taken into actual work in a quarry or mine. Only those in the explosive business seem to fully realize the difficulties in the way of a proper comparison of the value of two or more explosives. All of the points which I have just mentioned have their material effect on the value of an explosive, and much can be, and is, learned by study of an explosive at the laboratory, but the actual use of an explosive in practical work is necessary before a definite knowledge of the explosive can be obtained.

In this connection there is a point to which I wish to call your particular attention, and that is to the fact that the strength of a high explosive does not entirely depend upon the percentage of nitroglycerin in the explosive. Suppose you were making a test of two explosives, each containing the same percentage of nitroglycerin. One of these explosives may be found to be very much* stronger than the other, depending entirely on the other components of the explosive. This method of grading explosives by the percentage of nitroglycerin contents is still in general use and is very unfortunate both for the consumer and the reliable manufacturer of explosives. The consumer desires an explosive having the proper strength and action to do the work he has to do, without regard of the percentage of nitroglycerin in the explosive.

In the manufacture of explosives very careful attention is given to the method of manufacture. The purity of the raw materials, the intimate mixing of the ingredients, cartridge-making and packing are all essential points to be thoroughly studied in order to produce the best explosives.

Since 1886, in England and on the continent of Europe a study has been and is being made to-day of explosives suitable for use in gaseous and dusty coal mines. As a result of these investigations many explosives are manufactured for this class of work more suitable and which can be used with more comparative safety than blasting powder or dynamite. In the United States this is a newer problem, and yet according to Explosive Circular No. 3 issued by the United States Geological Survey of the Department of the Interior, on May 16, 1910, there are manufactured forty-five "Permissible" Explosives suitable for use in gaseous or dusty coal mines.

Where large quantities of fire-damp are found, it is ex-

tremely dangerous to use either blasting powder or ordinary dynamite for *this* reason. Blasting powder produces a very long flame of considerable duration and ordinary dynamite produces a very hot flame when exploded. Because of this and the explosive character of a mixture of fire-damp and air, or coal dust and air, or of all three of these occurring in coal mines, demands are made for the development of explosives which are not liable in their use to cause an explosion of any of these mixtures.

From laboratory tests it has been determined that certain gaseous mixtures require certain temperatures to ignite them. It has been found with considerable accuracy that fire-damp mixtures ignite at a temperature in the neighborhood of 650 degrees C., or 1202 degrees F. It is also necessary to heat the fire-damp mixtures up to the ignition point during a certain length of time. Consequently, the explosion of fire-damp depends on at least two factors, namely, *time* and *temperature*.

To determine the relative safety of explosives, the United States, as well as other countries, have established experimental stations. The apparatus used consists of an artificially constructed tunnel or gallery which can be filled with fire-damp and air, or other explosive gas or coal-dust mixture, and into which various sized charges of explosives can be fired from a mortar with or without tamping. The first fact established was that no explosive is absolutely safe, as all will ignite fire-damp when the charge per bore hole is sufficiently large, which is true even where the explosion temperature of an explosive is below 2000 degrees C., or 3632 degrees F.

Thus far we have dwelt only on the *temperature of detonation of explosives*, but after careful study of this subject it has been found that other factors in connection with the charge must be considered. These are the *rate or velocity of detonation*, the *length and duration of the flame*, the *heat of detonation* or the *quantity of heat produced*, the "*after flame*" ratio, or the relation between the rate of detonation and the duration of the flame, etc. All of these qualities have their effect on the safety of explosives in fire-damp, it having been shown that the lower they are, the safer the explosives. However, no limit can be placed on any of them, as excess in any other may counter-balance it. This point has been proven in the case of blasting powder, which

possesses all the necessary qualities for a safe explosive except the duration of the flame, which alone makes it very unsafe.

In looking over the field for the uses of explosives to-day, we find this list to be of much greater length than only a few years back. At one time we believed that explosives could be used only in quarries, mines of all kinds and railroad construction work. To-day we find that explosives are used in blasting stumps, boulders; tearing down buildings, breaking up hard pan and hard sub-soil, breaking up boilers and scrap iron, digging drainage ditches, breaking up log jams and ice jams, planting orchards and many other classes of work.

The E. I. du Pont de Nemours Powder Company of Wilmington, Delaware, are considered the largest manufacturers of explosives in this country. They manufacture all the different kinds of explosives for use in different kinds of work and have the largest force of expert chemists to carefully and thoroughly study the manufacture of explosives. They also maintain a Technical Division having a large field force to assist, wherever requested, in the better use of explosives in actual work.

All of the dynamites mentioned in this article are packed in cartridge form, the standard size of cartridges ranging from $\frac{7}{8}$ in. x 8 in. to 2 in. x 18 in., depending, of course, upon the kinds of explosives packed. As a general rule, they are packed in two sized cases, viz., 25-lb. cases and 50-lb. cases. The cases are made of one-half-inch lumber, lined with paper and a small amount of sawdust sprinkled in the bottom of each case according to regulations established by the Bureau for the Safe Transportation of Explosives.

Nearly all kinds of dynamite freeze at temperatures between 45° F. and 50° F. and they should be thoroughly thawed before using in order to obtain the full explosive effect. The low-freezing explosives, however, do not freeze much above the freezing temperature of water, yet these explosives should be thoroughly thawed when the temperature reaches the freezing point. The non-freezing explosives are, as their name suggests, truly non-freezing. As a general rule the "Permissible" Explosives used in the United States should be thawed before using if the temperature is below 50° F.

The thawing of dynamite is the cause of much loss of life, generally due to the fact that it is not given proper attention, as

many of the methods used are very crude. Too great care cannot be taken in the thawing of explosives, and it would be well for consumers of explosives to consult very freely with manufacturers on this important question.

In detonating dynamite, two methods are generally used; one by means of electricity and the other by use of safety fuse and blasting caps. Of these two methods the one most strongly recommended by explosive manufacturers for nearly all kinds of blasting is that by electricity, as it is the most effective, economical and safe system that can be used. This is especially true in coal mines, as when using safety fuze and blasting caps, the gas is apt to be ignited while lighting the fuse or by the spitting out of the fuse, while there is no danger in this respect when electricity is used.

Another very vital point to be considered in the use of explosives is the tamping material and the method of tamping the charge in the bore-holes. The best material to use is damp clay, for the reasons that it contains no gritty matter which will damage the fuze or electric fuze wires in tamping, and also it will pack well in the bore-hole and thus leave no air spaces. No inflammable material should ever be used. In tamping, the explosive should be well confined to obtain its maximum efficiency, and to insure the maximum resistance against the pressure of the gases of explosion.

Since 1886 as important results have been obtained in the manufacture, handling, storage and use of explosives as in the whole of the previous years. This is no doubt due to the enormous amount of scientific research and experiment devoted by manufacturers to the study of such questions and also demands made on manufacturers for different kinds of explosives. To-day every up-to-date manufacturer recognizes that only by the best scientific knowledge can he effect improvement or keep in line with modern developments of the industry.

FRANKLIN INSTITUTE

CHARTER AND BY-LAWS

The Franklin Institute

OF THE STATE OF PENNSYLVANIA FOR THE
PROMOTION OF THE MECHANIC ARTS.

An Act to amend and alter the Act incorporating the Franklin Institute of the State of Pennsylvania for the promotion of the Mechanic Arts.

WHEREAS, The Act approved March thirtieth, one thousand eight hundred and twenty-four, incorporating the Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, has been found insufficient and inconvenient for accomplishing the objects of said corporation, and the said corporation has applied for alteration and amendment thereof.

SECTION 1. Be it enacted by the Senate and House of Representatives of the Commonwealth of Pennsylvania, in General Assembly met, and it is hereby enacted by the authority of the same, that the present members of said corporation, and all such persons as may hereafter become members thereof, shall be, and are hereby created, a body politic and corporate by the name of the "FRANKLIN INSTITUTE OF THE STATE OF PENNSYLVANIA FOR THE PROMOTION OF THE MECHANIC ARTS," and shall have perpetual succession, be able to sue and be sued, to plead and be impleaded, to have and use a common seal, and the same to break, alter and renew at pleasure, and shall be able to take, hold, purchase and enjoy such real and other estates of any nature or kind whatsoever as they may obtain by purchase, devise, bequest or gift, and the same at their pleasure to sell, lease, mortgage, pledge, encumber, or dispose of as they may deem proper or convenient for promoting the objects of the said corporation; and the said corporation shall have the like power over any real estate or other estates now owned or held by them; *provided*, that the clear yearly value of the real estate at any time

held by them shall not exceed ten thousand dollars.

SEC. 2. That it shall be lawful for the said corporation to raise funds for the payment of its present indebtedness, and for all other purposes of the said corporation, to create and sell such number of shares of stock, at ten dollars each, as may be deemed proper to represent the estates of the said corporation, and the certificates of such stock shall be in such form, be transferable in such manner, subject to such payments, and entitle the holder thereof to such privileges, as the said corporation may, by its By-Laws in reference to such stock, grant and direct.

SEC. 3. The object of the said corporation shall be the promotion and encouragement of manufactures and the mechanical and useful arts, by the establishment of lectures on the sciences connected with them, by the formation of cabinets of models, minerals, machines, materials and products, by exhibitions and premiums, by a library and by all such measures as they may judge expedient.

SEC. 4. The members of the said corporation shall consist of manufacturers, mechanics, artisans, and persons friendly to the mechanic arts, and of such stockholders in said corporation as may, by the By-Laws, be entitled to the privileges of members; and every member shall pay such sum for an annual or life subscription as the By-Laws of said corporation may require; and honorary and corresponding members may be elected at such times, and in such a way, and with such privileges as said corporation may deem expedient.

SEC. 5. The said corporation shall be managed in such way, and by such number of officers, managers and other persons as the By-Laws may prescribe: and the powers and functions of such officers, managers or other persons, the rights and duties of members, the manner of their election, and the causes which may justify their expulsion or suspension, and all other con-

cerns of the said corporation, shall be fixed and regulated by its By-Laws, which By-Laws shall be adopted by said corporation at the first monthly meeting after the acceptance of this amended Charter, and said By-Laws shall be altered and amended only in the manner provided in said By-Laws as then adopted.

SEC. 6. So much of the Act to which this is a supplement as is inconsistent herewith is repealed.

OFFICE OF THE SECRETARY OF THE
COMMONWEALTH OF PENNSYLVANIA,

APRIL 25th, 1864.

I certify that the foregoing bill passed both branches of the Legislature, and received the signature of the Governor on this day. As witness my hand the day and the year above written.

(Signed.) ELI SLIFER,
Secretary of the Commonwealth.

BY-LAWS

ARTICLE I.—*Trustees.*

SECTION 1. All Real and Personal Estate of the Institute which may hereafter be acquired by voluntary subscription or devise, bequest, donation, or in any way other than through its own earnings or by investment of its own funds, saving where the donors shall expressly provide to the contrary, shall be taken as acquired upon the condition that the same shall be vested in a Board of Trustees, who shall be appointed in the manner hereinafter indicated. Unless the title to such property shall be directly vested in said Board of Trustees by the donors, the Institute, by deed attested by the President and Secretary, which they are hereby authorized to execute and deliver, shall forthwith convey the same to said Trustees, who shall hold it in trust for the purposes specifically designated by the donors; or, if there shall be no specific designation, for the benefit of the Institute in the way and manner hereinafter provided, so that the same shall not, in any event, be liable for the debts of the Institute.

SEC. 2. Said Board of Trustees shall be composed of seven (7) members, who shall be elected by the Board of

Managers from nominations made at a stated meeting of the Board at least one month prior to the election. Vacancies in the Board of Trustees shall be filled in the same manner.

The remaining members of the Board of Trustees, whenever at any time it shall be deemed necessary so to do, shall have power to assign and convey the property held by them, so as to vest the title thereto in themselves and their successors.

SEC. 3. Said Trustees shall have full power and authority, from time to time, to assign, sell and dispose of any property, real and personal, by them held, unless there shall be some direction by the donors to the contrary, and shall have power to convey the same without purchasers being obliged to see to the application of the purchase moneys, when authorized so to do by a vote of two-thirds (2-3) of the members present at any regular or special meeting of the Board of Managers, *provided*, that they shall not be obliged to sell or convey unless a majority of their own Board shall also approve.

SEC. 4. Said Trustees shall not be confined to legal investments, but shall have full power to invest in any real property, improvements and alterations, and in any securities, other than shares of stock, or unusual personal obligations, which to them may seem advisable.

SEC. 5. Said Trustees shall have power to appoint agents to act for them, and for the acts of such agents they shall not be personally responsible where they have exercised ordinary prudence in selecting them.

SEC. 6. Said Trustees shall have power to carry into effect any special trusts upon which any property may be held by them. They shall pay out all necessary and proper costs, charges and expenses, and from time to time shall pay over the net income to the Board of Managers, to be applied by them, to the uses of the Institute in accordance with the terms of the trusts from which the income is derived.

The principal and interest of all trust funds shall not be liable for debts of the Institute but shall be devoted to its continuance and preservation.

SEC. 7. At the annual meeting of the Board of Managers in each year, said Board of Trustees shall present a report of their proceedings and a detailed statement of their receipts and expenditures for the year. An approval of such account shall be final and conclusive, and shall bar any right to demand any other or further accounting.

SEC. 8. The Board of Trustees, at a meeting of the members of the Institute, called after three (3) months' special notice, at which the holders of nine-tenths (9-10) of the whole outstanding shares of stock shall vote affirmatively, may convey all property, real and personal, in them vested, to the Institute, free and clear of all trusts; *provided*, that there be no specific trusts violated by such conveyance, and that all the members of said Board, as the same shall then be constituted, shall approve of such conveyance.

ARTICLE II.—Stock.

SECTION 1. The Real and Personal Estates of the Institute as held upon the First day of January, One Thousand Eight Hundred and Eighty-one, shall be valued at One Hundred Thousand Dollars, and shall be represented by Ten Thousand Shares of Stock of the par value of Ten Dollars each. Said shares shall be divided into two classes, viz.:—

First Class.—Shares not registered for use: on which no annual payment shall be charged or collected, and the holders thereof shall not have the privileges of members of the Institute, but may, if of legal age, vote at any annual election for officers, managers and auditors, upon the payment of One Dollar upon each share of stock on which they may desire to vote; *provided, however*, such shares have been held by the same person at least three months before such election.

Shares of the First Class may be converted into shares of the Second Class at the pleasure of the owners, provided the transfer be approved by the Board of Managers; but, when once so converted, they shall always continue in the Second Class.

Second Class.—Shares registered for use: on which Twelve Dollars per annum shall be due and payable from resi-

dent members in advance on the first day of October in each year, except as hereinafter provided.

Non-resident holders of Second Class Stock shall pay an annual fee of Five Dollars.

SEC. 2. The holders of Second Class stock shall be entitled to the use of the library, lectures and reading-room; and, if of legal age, to all other privileges of membership in the Institute, so long as they make the annual payment in advance; and shall, on the payment of One Dollar therefor, be entitled to a Certificate of Membership.

SEC. 3. If the annual dues for two successive years remain unpaid at the expiration of two and a-half years on any share of stock of the Second Class, such share shall then become forfeited to the Institute; but such forfeiture may be remitted by a unanimous vote of the Board of Managers.

SEC. 4. Stock of the Second Class may be held in trust for persons not of legal age, and shall be liable to the payment of only one-half the annual fees due upon stock of Second Class held by persons of legal age; *provided*, that when such minors arrive at legal age, new certificates, subject to the full annual contribution, shall issue on payment of the customary fee.

SEC. 5. Certificates for the First Class stock may be issued for any number of shares in a single certificate; but every certificate for the Second Class shall be for one share only.

SEC. 6. No share of stock in the Second Class shall be transferred until all arrearages and fines are paid, and all books and tickets returned, and the transfer approved by the Board of Managers.

SEC. 7. All certificates of stock shall be signed by the President and Secretary; shall be issued by the Actuary, and shall be transferable only on the books of the Institute by the owner, or his legal representative, on the surrender of the old certificate, and of a fee of twenty-five cents for each certificate.

SEC. 8. All subscriptions to stock shall be approved by the Board of Managers before the certificate can be issued.

SEC. 9. The shares of stock obtained by the Institute by legacies, donations or forfeiture, shall at once be cancelled.

ARTICLE III.—*Members.*

SECTION 1. The members of the Institute shall consist of manufacturers, mechanics, artisans; and persons friendly to the mechanic arts, and they may be either annual contributors, associate members, life members, permanent members, holders of Second Class stock, honorary or corresponding members.

SEC. 2. The privileges of membership, other than associate membership, in the Institute shall extend only to persons of legal age who are not in arrears and who shall have signed the Charter and By-Laws.

SEC. 3. Annual contributors shall pay yearly dues of Fifteen Dollars; shall be entitled to all of the privileges of the Institute, and shall be eligible to any office or to membership upon any committee.

SEC. 4. Non-resident annual contributors shall pay an entrance fee of Five Dollars and annual dues of Five Dollars.

SEC. 5. Associate members shall be over seventeen and under twenty-five years of age. They shall have the right to attend all meetings of the Institute, use the library, receive the Journal and serve upon committees, but they shall not have the right to vote or to hold office. They shall pay annual dues of Five Dollars. The term of an associate member shall be limited by the age of twenty-five years after which he shall become an annual contributor with the dues and privileges of that class and he shall be duly notified of the transfer.

SEC. 6. Annual contributors whether resident, non-resident or associate members shall be elected by the Board of Managers.

SEC. 7. Honorary and Corresponding Members shall be nominated by the Board of Managers, and shall require for their election four-fifths of the votes of the members present at any meeting of the Institute at which their nomination may be acted upon. They shall pay no dues.

SEC. 8. Life members, whose membership shall not be transferable, may

be elected by the Board of Managers upon the payment of Two Hundred Dollars in any one year.

Non-resident Life members may be elected in the same way upon payment of Seventy-five Dollars in any one year.

SEC. 9. A permanent membership, which may be transferred by will or otherwise, subject to the approval of the Board of Managers, may be granted by the Board of Managers to any one who shall contribute to the Institute for that purpose the sum of One Thousand Dollars in any one year.

SEC. 10. Non-resident members shall be those who reside permanently at a distance not less than twenty-five miles from Philadelphia. Transfers of membership from the resident to non-resident class may be granted by the Board of Managers at its discretion in cases of temporary absence of a member from the city for a period of not less than one year.

SEC. 11. Members shall be entitled to a Certificate of Membership on payment of One Dollar.

SEC. 12. Resignations of membership shall be made to the Board of Managers in writing, but shall not be accepted until all dues, fines, and arrears of dues and current dues at the annual rate up to the date of resignation, shall have been paid, and books and tickets returned.

ARTICLE IV.—*Payments of Dues.*

SEC. 1. The annual payment of fees for membership shall be due and payable on the first of October in each year, in advance; but all members elected after the 31st of January in each year shall pay, in advance, the proportionate amount of the annual dues for the remaining months of the Institute year.

SEC. 2. Any member whose dues are more than three months in arrears shall be notified by the Actuary. Should such dues not be paid when they become six months in arrears, the privileges of membership shall by that fact be suspended. When nine months in arrears such member shall be again notified, and if such dues become one year in arrears, the said member shall by that fact forfeit all connection with

the Institute. The Board of Managers, however, may, for cause by it deemed sufficient, extend the time for payment and for the application of these penalties.

The Board of Managers may, for sufficient cause, temporarily excuse from payment of annual dues any member who from ill health, advanced age, or other good reason assigned, is unable to pay such dues; and the Board may remit the whole or part of dues in arrears or accept in lieu thereof service or material contributed to the Institute.

SEC. 3. Every person admitted to membership in the Institute shall be considered as liable for the payment of dues until he shall have resigned, been dropped or have been relieved therefrom by the Board of Managers.

SEC. 4. The annual dues from contributing members may be applied to the current expenses of the Institute, but all moneys received from life and permanent membership shall be vested in the Board of Trustees, the income therefrom only to be applied to the maintenance fund.

ARTICLE V.—*Officers.*

The officers shall be a President, three Vice-Presidents, a Secretary, a Treasurer, and twenty-five Managers. A majority of the Managers shall be persons directly interested in industrial pursuits.

ARTICLE VI.—*Election of Officers.*

SECTION 1. An election for officers shall be held on the third Wednesday in January in each year. At this election the President and the Treasurer shall be elected to serve one year, and one Vice-President, and eight Managers, shall be elected to serve for three years; *provided*, that the officers now elected or who may hereafter be elected, shall continue to serve until their successors be elected.

One Manager, to be known as the Alumni Manager, shall be elected in January of every third year, beginning in the year 1910, by the Alumni Association of the Institute, to serve for three years. A vacancy in this position shall be filled by election in the same manner for the unexpired term.

The Secretary shall be elected by the Board of Managers at their first stated meeting after the annual election each year.

SEC. 2. All elections for officers of the Institute shall be by letter ballot, and no vote may be cast by proxy, nor received from a member in arrears.

SEC. 3. Nominations for the annual election for officers shall be presented in writing at the stated meeting in the month of December. Each nomination paper must be signed by at least two members in good standing, who shall certify that the candidate will serve if elected. After the nominations are closed, the President shall appoint three members, who are neither officers nor nominees, to act as tellers of the election. The list of nominees shall promptly be posted at the Institute and incorporated (with directions for voting) in a ballot to be sent to each member by the Secretary at least one week before the date of the election. Each ballot shall be accompanied by a return envelope addressed "To the Tellers of Election," and provided with a space for the signature of the member voting.

SEC. 4. On the date of the annual election, and at an hour previously designated by their chairman, the tellers shall meet at the Institute and shall count all legal votes that have been received by mail or placed in the ballot box before 8 o'clock P. M.; and when the count is completed they shall report to the annual meeting of the Institute the total number of ballots cast, together with the number of votes received by each candidate. Thereupon the presiding officer shall announce the names of the candidates who received the plurality of votes for each office, and shall declare them elected officers of the Institute for the ensuing terms.

ARTICLE VII.—*President.*

It shall be the duty of the President, or, in his absence, of one of the Vice-Presidents, in order of seniority of election, or, in their absence, of a President to be chosen *pro tempore*, to preside at all meetings of the Institute and of the Board of Managers.

ARTICLE VIII.—*Secretary.*

SECTION 1. The Secretary of the Institute shall be a person of scientific attainments. He shall receive such salary as may be fixed by the Board of Managers.

SEC. 2. He shall have general charge and supervision, subject to the Board of Managers, of all the work of the Institute, and of its library, museum, laboratories, and property in general.

SEC. 3. He shall keep the minutes of all meetings of the Institute; and shall perform all the duties usually pertaining to the office of secretary.

SEC. 4. He shall be *ex officio* a member of the Board of Managers and of all standing committees of the Institute.

SEC. 5. As *ex officio* Secretary of the Committee on Science and the Arts he shall attend all meetings of that Committee and keep the minutes thereof. He shall also attend meetings of sub-committees at which his attendance has been requested, and when desired shall aid sub-committees in making searches and in the examination of authorities, documents, apparatus, etc.

Two weeks before each stated meeting of the Committee he shall report to its Chairman the status of all investigations pending before the sub-committees.

He shall also perform any other duty that may tend to advance the work of the Committee.

With the approval of the Board of Managers he may appoint an assistant to perform some, or all of his duties as Secretary of this Committee.

ARTICLE IX.—*Treasurer.*

It shall be the duty of the Treasurer to receive from the Board of Trustees all funds, which they may pay over to the Board of Managers in accordance with Section 6 of Article I. He shall also receive all moneys collected for the Institute by the Actuary. He shall deposit all moneys received, in the name of the corporation, in such institution as the Board of Managers may direct. He shall make no payments without written vouchers from the Board of Managers. He shall keep accurate accounts of the income and disbursements of the Institute, exhibit an accurate statement of his receipts and payments at each stated meeting of the

Board of Managers, and of the condition of the finances of the Institute whenever called on by them, and shall make an annual statement thereof at the annual meeting of the Institute. He shall give bonds to an amount fixed by the Board of Managers for the faithful performance of his trust. In case of a vacancy in the office of treasurer, it shall be the duty of the Board of Managers to appoint a person to perform the duties of the position *pro tempore*.

ARTICLE X.—*Board of Managers.*

SECTION 1. The Board of Managers shall consist of 25 members elected as provided in Article VI; all officers of the Institute, *ex officio*, except the Trustees; and the Chairman of the Committee on Science and the Arts, *ex officio*.

The Board of Managers shall have entire charge and control of the current receipts and expenditures of the Institute, and of all its business affairs not specially reserved to the Board of Trustees, and shall have authority to do all acts not inconsistent with the rights and duties of the Trustees which may in their judgment advance the interests of the Institute.

They shall have authority, by exchange, sale or otherwise, to add to or subtract from the collections of books, furniture and apparatus, in such manner, however, that the aggregate value of the same to the Institute, at any time, may not be impaired.

They shall have authority to elect members of the Institute, except Honorary and Corresponding Members, who shall be elected by the Institute.

SEC. 2. They shall keep regular minutes of their proceedings, which shall be open at all times to inspection by members of the Institute.

SEC. 3. They shall present at the annual meeting of the Institute, a report of their proceedings and of the condition of the affairs of the Institute.

SEC. 4. They shall hold stated meetings once in each month. They shall elect their own officers, except the chairman, who shall be the President of the Institute, or in his absence, as provided for in Article VII, and shall be at liberty to make by-laws for their own regulation not inconsistent with

the Charter, or with the By-Laws of the Institute. Seven of their members shall constitute a quorum.

SEC. 5. All vacancies in the Board of Managers shall be filled by an election at the next stated meeting of the Institute.

ARTICLE XI.—*Audits.*

The accounts of the Treasurer and Board of Trustees shall be audited at least once a year by certified public accountants, who shall report to the Board of Managers.

ARTICLE XII.—*Committees of the Institute.*

SECTION 1. There shall be the following Standing Committees, each to consist of ten members, to be appointed by the President, at the first meeting after the annual election, who may be aided in his choice by nominations made at the annual meeting. All members notified of their appointment to any committee, if they do not decline before the next stated meeting, shall be considered members thereof:—

1. On the Library.
2. On the Museum.
3. On Meetings.

SEC. 2. There shall be a Committee on Science and the Arts, consisting of sixty members of the Institute, who shall pledge themselves by their acceptance of membership to perform such duties as may devolve upon them and to sustain by their labors the scientific character of the Institute.

They shall be elected by the Board of Managers at its stated meeting on the fourth Wednesday of January, twenty members being elected each year to serve for three years.

The Secretary shall report to the Board of Managers at said meeting the number of vacancies on the Committee from any cause, and the names of those whose terms expire that year, together with the record of their attendance at meetings of the Committee, and a brief summary of their participation in the work of the Committee and its sub-committees. Vacancies occurring during any year may be filled by the Committee itself by election of members to serve until the following January.

Within one month after the Annual

Election, the Committee shall hold a meeting at which it shall elect a Chairman for the current year.

It shall be the duty of the Committee to investigate and report upon any subject referred to it by a vote of the Institute, or any Section thereof, and at its discretion to investigate other subjects on application.

Applications for the examination of any subject shall be made to the Committee, either by recommendation of the Institute, or any Section thereof, or by requests from inventors or others, under the regulations of the Committee.

It shall also be the duty of the Committee to make or recommend the award of medals and other forms of recognition established by, or in charge of, the Institute.

Sub-committees to examine any subject shall be appointed by the Chairman of the General Committee from its membership, but they may include a minority of persons who are not members of the General Committee or of the Institute, but whose expert services are desired in the examination.

Reports of sub-committees shall be made to the General Committee in writing.

Final action on a report conferring or recommending an award shall not be taken by the General Committee except at the second of two successive stated meetings at which it has been read and been open for discussion and amendment.

A quorum for final action upon a report conferring or recommending an award shall consist of not less than fifteen members, and when such report is adopted it shall be accepted as the decision of the Institute.

Reports when issued after final adoption shall set forth that they are the action of the Franklin Institute by its Committee on Science and the Arts. They shall be signed by the President and the Secretary of the Institute and by the Chairman of the Committee; and the seal of the Institute shall be affixed thereto. The Committee may provide that such reports shall also be signed by the members of the respective sub-committees who made the investigations and prepared the reports.

The Chairman of the Committee shall submit to the stated meetings of the Board of Managers in October, Decem-

ber, February, April, and June of each year, a report of the number of investigations pending before the Committee, the number disposed of since the last report, with the action taken or award made in each case, and the number and nature of new investigations undertaken since the last report, and such other information as to the work of the Committee as the Board of Managers may require.

He shall also report to the stated meetings of the Institute such recent action of the Committee as he may deem of interest.

At the request of the Committee on Publications, and to make an adopted report more suitable for the use in the Journal of the Institute, the sub-committee that prepared the report shall have authority to amplify or abridge it without in any way changing its meaning or recommendation for award; but the fact of such modification must be stated as a note at the beginning of its publication in the Journal.

SEC. 3. Each committee named in the first and second sections shall choose a chairman at its first meeting after its appointment.

Record of their proceedings shall be kept by the Secretary. They shall report to the Institute, and when required to the Board of Managers.

They shall be governed by such rules, not inconsistent with these By-Laws, as may be adopted by them respectively.

The Committees on the Library, on Meetings, and on Science and the Arts, shall meet at least once in each month, except in July and August.

SEC. 4. No bills for expenses incurred by committees shall be paid unless approved by the Committees which incurred them.

ARTICLE XIII.—*Meetings.*

SECTION 1. The Institute shall hold stated meetings on the third Wednesday of each month, except in July and August. That on the third Wednesday in January of each year shall be the annual meeting.

SEC. 2. Special meetings shall be called by order of the President, upon request of the Board of Managers, or the written application of twelve members of the Institute. Fifteen members shall constitute a quorum.

ARTICLE XIV.—*Order of Business.*

SECTION 1. The stated meetings of the Institute shall be held at the hour of 8 o'clock P. M.

SEC. 2. The order shall be as follows;

1. Reading of the Minutes.
2. Reports from the Board of Managers.
3. Reports from the Standing Committees, etc.
 - (1). On the Library.
 - (2). On the Museum.
 - (3). On Meetings.
 - (4). On Science and the Arts.
4. Reports from Special Committees.
5. The paper announced for the evening.
6. The Secretary's report.
7. Deferred business.
8. Consideration of new business.

SEC. 3. At the annual meeting, the tellers' report may be received and read by the Secretary immediately after the conclusion of any number of the order of business.

SEC. 4. The order of business may be altered for any meeting by a vote of two-thirds of the members present thereat.

ARTICLE XV.—*Rules.*

The Institute, at its meetings, shall be governed by Roberts' Rules of Order.

ARTICLE XVI.—*Organization and Government of Sections.*

SECTION 1. For the promotion and encouragement of manufactures and the mechanic arts, as well as of the sciences connected with them, members of the Institute may form sections and hold meetings in such rooms as may be provided for them by the Board of Managers. These sections shall be constituted as hereinafter provided, and shall have precedence in the order of their formation.

SEC. 2. Any number of members, not less than twelve, may constitute a section.

SEC. 3. Members desiring to form a section shall make written application to that effect to the Committee on Sectional Arrangements, which committee shall report such applications to the Board of Managers.

If the application shall be approved

by the Board of Managers, the section shall be established and the names of the petitioners shall be recorded on the minutes as the founders of that section, and shall be reported by the Board of Managers to the Institute at its next meeting. Whenever the petitioners shall have organized, they shall report such organization, with the names of their officers, to the Committee on Sectional Arrangements. But if they shall fail to organize such section within six months after the date of said approval, or if an established section shall fail to make a report of its proceedings to the committee during any period of twelve months, it shall be the duty of the Committee on Sectional Arrangements to inform the Board of Managers, which may thereupon declare that such section is extinct.

SEC. 4. All members of the Institute shall have the privilege of enrolling themselves, without payment of additional fees, as members of any of the sections which are now, or which may hereafter be, established in conformity with these By-Laws, and such enrollments shall be reported from month to month to the secretaries of the sections designated; but no person shall be entitled to any of the privileges of any of the sections who has not complied with the conditions of Article III of these By-Laws.

SEC. 5. Each section shall submit to the Committee on Sectional Arrangements prior to the stated meetings of the Board of Managers in December of each year, an estimate of moneys it will require for the ensuing year, and such estimate the Committee on Sectional Arrangements shall transmit, with its recommendation, to the Board at its stated meeting in December.

SEC. 6. Each section shall elect its own officers and make its own by-laws, not inconsistent with the Charter and By-Laws of the Institute. The Institute shall not be responsible for bills contracted by any section in conformity with the conditions prescribed in Section 4 of Article XII of the By-Laws relating to committees, nor in any event for a sum greater in any one year than the amount appropriated by the Board of Managers for the service of the section for that year.

SEC. 7. All requisitions for supplies

shall be made by order upon the Actuary of the Institute.

SEC. 8. The books, papers, apparatus, specimens, models and all other collections of each section, shall be the property of the Institute, held for the use of that section. Donations of objects or books to or for any section, shall be received and reported to the Committee on Sectional Arrangements, and by this committee to the Board of Managers, as donations to the Institute for the use of that section.

SEC. 9. Each section shall determine, subject to the approval of the Board of Managers, the times of its stated meetings.

SEC. 10. Papers read and lectures delivered before any section and approved by the same, shall be referred to the Committee on Publications of the Institute, and if accepted by them, shall be published in the *Journal* of the Institute.

SEC. 11. Societies now existing, or which may hereafter be founded, for the consideration of any subjects clearly within the scope of the Franklin Institute, and which societies may desire to unite with the Franklin Institute as sections, shall furnish a list of such of their members as have declared their willingness to become members of the Institute, to the Committee on Sectional Arrangements, which committee shall transmit the same, with its recommendation, to the Board of Managers.

SEC. 12. On all points not herein provided for, each section shall be governed by the Charter, By-Laws and usages of the Institute.

ARTICLE XVII.—*Amendments.*

Proposals for amendments to these By-Laws shall be presented in writing, signed by two members in good standing, at any stated meeting of the Institute. By a majority vote of the members present at this meeting they may be considered, amended, referred, postponed, rejected, or ordered to be voted upon at the date of the next stated meeting, until which time they shall be posted at the Institute. The final vote upon amendments shall be by ballot, and if two-thirds of the votes cast are in favor of any proposed amendment, it shall be declared adopted; except that amendments to Article II, re-

lating to capital stock, must (subsequently) be ratified by a majority of the stock represented at a meeting specially called for this purpose.

BY-LAWS OF THE BOARD OF MANAGERS

SECTION 1. *Officers.*—The President of the Institute, or, in his absence, the Vice-President, in order of seniority of election, or in the absence of both, a member elected *pro tempore*, shall preside at all meetings of the Board. Records of its proceedings shall be kept by the Actuary.

SEC. 2. *Meetings.*—The Board shall hold a meeting for the purpose of organizing, electing a Secretary, and a Committee on Science and the Arts; and appointing an Actuary, Standing Committees, etc., on the fourth Wednesday in January, and regular meetings on the second Wednesday of each month, at 3.30 o'clock P. M.

SEC. 3. Special meetings may be called by the President at his discretion, and shall be called on written request of five members of the Board. In case of his absence or refusal to act, such special meeting shall be called by the Actuary.

SEC. 4. *Actuary.*—An Actuary shall be appointed by the Board at their first meeting after the annual election. He shall keep a correct record of their proceedings; keep a roll of the members, and note their attendance thereon; give notice of all meetings of the Board, and of committees, delivered at least two days prior to the day of meeting; act as Secretary of all Standing Committees of the Board; notify all committees of the Board of their appointment, and transmit to the chairman of each all papers or documents relating to the subject to be considered or acted upon. He shall collect and receive all moneys due to the Institute, and hand them over to the Treasurer; shall act as agent of the *Journal* of the Institute, and shall transact such other business of the Institute as the Board shall direct. In all matters he shall be subject to the direction and control of the Board, and he shall receive such yearly compensation as they may determine.

SEC. 5. *Resignations.*—All resignations by members of the Board, after

acceptance thereof, shall be reported to the Institute at its next stated meeting.

Members who have not attended six regular meetings prior to the stated meeting of the Institute in December, shall be reported thereat as having resigned, unless it be unanimously voted by the Board, at its stated meeting in December, that such member has been absent for sufficient reason.

SEC. 6. *Standing Committees.*—The following Standing Committees, consisting of five members each, shall be appointed by the President and approved by the Board:—

1. On Instruction. 2. On Election and Resignation of Members. 3. On Stocks and Finance. 4. On Publications. 5. On Exhibitions. 6. On Sectional Arrangements. 7. On Endowment.

It shall be the duty of these committees to keep regular minutes of their proceedings, and report monthly to the Board, and to report to the stated meeting of the Board in December an estimate of moneys they require for the service of the ensuing year.

SEC. 7. *Professorships.*—The Board may, at its discretion, establish such Professorships as may seem advisable, and on such subjects as it may designate, to serve until the next succeeding first meeting after the annual meeting.

SEC. 8. *Order of Business.*—The order at the stated meetings shall be as follows:—

1. Calling the roll.
2. Reading the minutes and acting thereon.
3. Report from Treasurer, and action on bills.
4. Reports from Standing Committees, and action thereon.
 - (a). On Instruction.
 - (b). On Election and Resignation of Members.
 - (c). On Stocks and Finance.
 - (d). On Publications.
 - (e). On Exhibitions.
 - (f). On Sectional Arrangements.
 - (g). On Endowment.
5. Reports from Special Committees and action thereon.
6. Deferred Business.
7. New Business.

SEC. 9. *Amendments.*—These By-Laws may be altered at any stated meeting of the Board, provided the alteration be approved by two-thirds of the members present.

FRANKLIN INSTITUTE

REGULATIONS OF THE COMMITTEE ON SCIENCE AND THE ARTS OF THE FRANKLIN INSTITUTE

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, May 12, 1909, and approved by the Institute at its stated meeting held December 15, 1909.

ARTICLE I.—*Meetings.*

SECTION 1. The Committee shall hold a stated meeting at 8 o'clock P.M., on the first Wednesday of each month, excepting July and August. Special meetings may be called by the Chairman, and shall be called by him upon the written request of five members of the Committee.

SEC. 2. At all meetings of the Committee nine members shall constitute a quorum for the transaction of general business but for final action upon a report conferring or recommending an award a quorum shall consist of not less than fifteen members.

SEC. 3. At its stated meetings the Committee shall proceed in the following

Order of Business

1. Calling the roll.
2. Reading of the minutes of preceding meeting.
3. Reading of correspondence.
4. Report of subcommittee on Preliminary Examination.
5. Report of subcommittee on New Subjects and Publicity.
6. Consideration of reports for final action.
7. Reports of subcommittees of investigation, first reading.
8. Deferred business.
9. New business.
10. Adjournment.

SEC. 4. Members may speak twice on any question except as otherwise provided but not oftener without the consent of the Committee.

SEC. 5. There shall be no debate on points of order except on an appeal from the decision of the Chairman, or on a question referred by him to the Committee. In such cases no member shall speak more than once, unless by consent of the Committee.

ARTICLE II.—*Chairman.*

SECTION 1. Nominations for a chairman to serve for one year shall be made at the stated meeting of the Committee in February, and the election shall be by ballot at the same meeting, when the person receiving the highest number of votes shall be declared elected. He shall immediately assume his office and shall perform its duties until his successor shall be installed. He shall not be eligible for election in successive terms.

SEC. 2. The Chairman shall appoint the members of all subcommittees, unless otherwise ordered and may serve *ex officio* on all subcommittees, except on those charged with investigations.

Whenever he shall ascertain that any member of a subcommittee fails to discharge his duties, he is empowered to substitute another member.

ARTICLE III.—*Investigations and Reports.*

SECTION 1. By a vote of a majority of the members present at any stated meeting, it shall be competent for the Committee to investigate any subject which may be presented on the motion of a member, or by application as herein provided.

SEC. 2. Every applicant who may submit a subject to the Committee for investigation, shall be furnished by the Secretary with a copy of the rules and regulations of the Committee governing investigations.

SEC. 3. Applications for investigation of any subject shall be made to the Secretary of the Institute in writing on blank forms to be furnished by him

(substantially in the form hereto annexed and marked form "A"), and upon acceptance or rejection of the same he shall notify the applicant accordingly.

SEC. 4. There shall be a special subcommittee, to be appointed by the Chairman, and to be styled the "Subcommittee on New Subjects and Publicity;" the purpose of which shall be to keep a general observation, so far as it can, of progress made in science and the arts, and to report to the Committee subjects worthy of investigation; and also to co-operate with the Secretary in keeping the work of the Committee properly before the public. It shall report to the Committee at the stated meetings in February, April, June, September and December of each year.

SEC. 5. There shall be a special subcommittee to be appointed by the Chairman, and to be styled the "Subcommittee on Preliminary Examinations." All applications for investigation shall be at once referred by the Secretary of the Institute to this subcommittee, except in case of subjects referred to the Committee by the Institute or by any section thereof or by the subcommittee on "New Subjects and Publicity," which subject shall come directly to the Committee.

The Subcommittee on Preliminary Examinations shall meet, at least once prior to each regular meeting of the Committee, and after making a preliminary examination of the subjects of applications referred to it shall report to the committee at each regular meeting what applications in its judgment should be accepted and what declined.

SEC. 6. There shall be a special subcommittee to be appointed by the chairman with the consent and approval of the general committee and to be styled the "Subcommittee on Literature."

It shall be the duty of this subcommittee to examine carefully all papers that have been presented to the Institute and published in its JOURNAL during the current year and to report at the following January meeting to the general committee which of said papers, if any, in its judgment deserve the award of either of the following medals, viz:

1. *The Potts Gold Medal;*
2. *The Longstreth Silver Medal.*

The Committee may at its discretion, award said medals to the authors of papers and reports so recommended except that they shall not award more than one Potts medal in any one year.

The medals shall be sent to the authors to whom they are awarded, together with a certificate of their award signed by the President and Secretary of the Institute and the chairman of the committee.

If for sufficient reasons, the Committee on Literature does not recommend any or all of these awards, during any year, the award may be omitted for that year.

SEC. 7. No person shall be a member of a subcommittee of investigation who is or has been interested in the issue.

SEC. 8. A quorum for the transaction of business at any meeting of a subcommittee properly called, shall consist of any two or more members present.

SEC. 9. No applicant or other person interested in the issue of an investigation shall be present at a meeting of a subcommittee or of the general committee when a subject of invention in which he is interested shall be under discussion, except at the invitation of the subcommittee charged with the investigation; but after the report of the subcommittee has passed its first reading, he may examine it, on application to the Secretary, and may make any explanations or objections, in writing, addressed to the Chairman of the general committee; provided that such explanations or objections shall be submitted not later than the next stated meeting of the general committee.

SEC. 10. No subject or invention can be withdrawn after it has been assigned to a subcommittee for investigation without the consent of the general committee.

SEC. 11. Each subcommittee of investigation shall report its progress, and conclude with its final report, to the general committee, at intervals of not more than two consecutive stated meetings; and any subcommittee failing so to report for four consecutive meetings may be discharged from further consideration of the subject at the discretion of the chairman, who shall then appoint

a new subcommittee to continue the investigation.

SEC. 12. Subcommittees in preparing their reports shall accompany them with drawings or diagrams, whenever these will serve to illustrate the subject of their reports; and they shall be authorized, whenever they shall deem it necessary, to require applicants to furnish such drawings or diagrams as a condition precedent to such investigations and reports.

SEC. 13. Reports on all subjects must be signed by a majority of the members of the subcommittee charged with the investigation. Minority reports shall be received and by a vote of a majority of the members of the general committee may be considered.

SEC. 14. The Committee shall award the medals and other forms of recognition established by or in charge of the Institute, as directed by the By-Laws thereof.

SEC. 15. When any subcommittee of investigation deems the subject upon which it reports worthy of an award of the Elliott Cresson Medal, the Howard N. Potts Medal, the Edward Longstreth Medal of Merit, Certificate of Merit, or the John Scott Legacy Premium and Medal it shall conclude its report with a recommendation to that effect and such recommendation shall not be changed by the general committee except by a vote of two-thirds of the members present.

SEC. 16. It shall not be competent for any member of the Committee on Science and the Arts to be a competitor for any of the medals or other awards in the gift, or subject to recommendation of the said committee, unless the subject for award be referred to the Committee for examination by a vote of the Institute.

SEC. 17. No final report of a subcommittee of investigation shall be considered at any meeting of the general committee unless at least one member of the subcommittee signing the report is present.

SEC. 18. The reports of all subcommittees may be discussed and amendments proposed at the meeting of the general committee at which they are

first presented, but both report and amendments shall be laid over for a second reading and final action until the next stated meeting, except that where no recommendation of an award is included in the report, it may be, by a majority vote, taken up for second reading and finally disposed of.

SEC. 19. It shall be the duty of the Secretary to certify to the applicant the action of the general committee, and to furnish to the said applicant one copy of its report within ten days after the same shall have been finally adopted, except in cases where the Committee has made or recommended an award, when the copy shall neither be furnished the applicant nor published except by title during the time in which proper objections to such award, or motion for reconsideration, may be made, but the report may be seen by any person on application to the Secretary. In default of such motion or objection, the previous action upon a report and award shall be final.

SEC. 20. A motion for the reconsideration of a report may be made not later than the next stated meeting after its adoption and may be acted upon at the next following stated meeting, when a vote of two-thirds of a quorum for final action shall be necessary to amend the report as previously adopted. A second investigation of the same subject shall not be ordered, except on a vote of two-thirds of the members present at a stated meeting.

SEC. 21. Reports when issued after final adoption shall set forth that they are the action of the Franklin Institute by its Committee on Science and the Arts. They shall bear the names of all the members of the respective subcommittees who made the investigations and signed the original reports, and shall be attested by the President and Secretary of the Institute and by the Chairman of the committee and stamped with the seal of the Institute.

SEC. 22. In all cases where awards are given for compounds, specimens thereof shall be furnished the Institute to keep in its Museum as evidence of the subject of the award.

And all other subjects investigated and for which awards are made, which

may be presented to the Institute, shall be preserved in the Museum.

ARTICLE IV.—*Amendments.*

Proposals to amend the regulations shall be made at a stated meeting in writing and signed by at least two members. They may be considered when presented, but shall not be acted upon until the next stated meeting, and shall be adopted if then agreed to by two-thirds of the members present. In all cases, notice of proposed amendments shall be sent to each member on the program for the meeting at which they may be acted upon.

Regulations Governing Subcommittees of Investigation.

Appointments.—When the personnel of a subcommittee of investigation is finally determined, a notice shall be sent to each member thereof giving the names of members of the committee and setting forth regulations governing investigations.

Meetings.—Meetings are to be held at the Institute when possible and all notices of meetings are to be sent from the Secretary's office.

Information.—When the Secretary has obtained the necessary information from the applicant, he shall notify the subcommittee who may then proceed with the investigation. When data or tests are submitted by other than the members of the subcommittee, it shall be so stated in the report.

Reports.—All final reports are to have a uniform beginning and ending, and are to be typewritten on official paper of the Institute.

Signing.—Reports must be signed by a majority of the subcommittee before they are filed with the Secretary. No member of a subcommittee is permitted to sign a report without having personally examined the subject under investigation, or having taken part in a discussion of its merits at a meeting of a subcommittee. The chairman of the subcommittee, through the Secretary of the Institute, must give formal and ample notice to the other members before making official examination or tests.

Minority.—Any member or members of a subcommittee can file a minority report at least three days prior to the

meeting at which the report is to be considered and copies of such minority report shall be distributed to the general committee with the report of the majority.

Reports.—The final reports must be in the Secretary's hands at least one week previous to the general meeting.

Correspondence.—Correspondence between the subcommittee and applicant must be carried on through the office of the Secretary, in order that the official records shall be kept complete.

Litigation.—When the subcommittees find the subject under investigation is entangled in litigation, it shall defer action and report to the general committee. No further action can be taken unless the litigation is terminated or the general committee decide that the subcommittee is to proceed.

Genuine Samples.—Subcommittees must make certain that articles, processes, products, etc., examined are genuine samples of the subjects under investigation.

Accuracy of Tests and Data.—Subcommittees shall make sufficient investigations, tests, etc., of their own and shall not accept tests, data or information furnished by others, without first satisfying themselves as to the care exercised in making or gathering same and the accuracy thereof. They shall in no case recommend an award solely on tests, data or information furnished by parties in any way interested in the subject of the award.

Awards by the Institute.

The Institute, through its Committee on Science and the Arts, in accordance with the regulations as set forth herein, is entrusted with the award of the following Medals and Certificate of Merit:

The Elliott Cresson Medal,

The Howard N. Potts Medal,

The Edward Longstreth Medal of Merit,

The Certificate of Merit,

Recommendation to the Board of City Trusts, of the award of the John Scott Legacy Premium and Medal.

The significance of these awards, in order of their importance, is as follows:

The Elliott Cresson Medal (Gold Medal and Diploma).—This medal shall be awarded for discovery or original investigation, irrespective of commercial

value, adding to the sum of human knowledge; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (Gold Medal).—This medal shall be awarded for distinguished work in science or the mechanic arts; important development of previous basic discoveries; and inventions or products utilizing important principles or of superior excellence or for papers of superior excellence presented to the Institute and published in its JOURNAL.

The Edward Longstreth Medal of Merit (Silver Medal and Diploma).—Money Premium only when Accumulated Interest of the Fund permits. This medal shall be awarded for Meritorious work in science or the industrial arts; including papers relating to these subjects originally presented before the Institute or for meritorious papers presented to the Institute and published in its JOURNAL.

In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it shall be competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that the committee may consider of sufficient importance or for meritorious papers presented to the Institute and published in its JOURNAL.

Certificate of Merit.—Certificate of Merit shall be awarded to persons adjudged worthy thereof for their inventions, discoveries or productions.

In addition to the foregoing awards by the Institute, the Board of City Trusts of the City of Philadelphia awards the following premium and medal on the recommendation of the Institute, namely;

The John Scott Legacy Premium and Medal (Bronze Medal, Diploma and Premium of \$20).—Awarded by the Board of City Trusts of the City of Philadelphia on recommendation of the Franklin Institute, acting through its Committee on Science and the Arts, by the terms of the deed of gift "to ingenious men and women who make useful inventions."

ADVERTISEMENT OF AWARDS

The following special rules regarding the advertisement of the awards shall be observed:

1. Upon the adoption, by the Committee on Science and the Arts, of a report setting forth that a discovery, invention, improvement or manufacture is worthy of an award of the Elliott Cresson Medal, publication shall be made in three successive issues of the JOURNAL OF THE FRANKLIN INSTITUTE, stating that at the expiration of three months from the date of the first publication, the applicant will be entitled to receive the award of the said medal, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality or merit in the supposed discovery, invention, improvement, or manufacture.

2. Upon the adoption, by the Committee on Science and the Arts, of a report setting forth that distinguished work in science or the arts is worthy of an award of the Howard N. Potts Medal, publication shall be made in three successive issues of the JOURNAL OF THE FRANKLIN INSTITUTE, stating that at the expiration of three months from the date of the first publication, the applicant will be entitled to receive the award of the said medal, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality or merit in the supposed distinguished work in science or the arts.

3. Upon the adoption, by the Committee on Science and the Arts, of a report setting forth that meritorious work in science or the arts is worthy of an award of the Edward Longstreth Medal of Merit, publication shall be made in three successive issues of the JOURNAL OF THE FRANKLIN INSTITUTE, stating that at the expiration of three months from the date of first publication, the applicant will be entitled to receive the award of the said medal, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality or merit in the supposed meritorious work in science or the arts.

4. The adoption by the Committee on Science and the Arts of a report setting forth that meritorious work is worthy of an award of the Certificate of Merit, shall be conclusive, without the advertisement that is required in the case of other awards by the Committee.

5. Upon the adoption by the Committee on Science and the Arts of a report setting forth that an invention or improvement is worthy of an award of the John Scott Legacy Premium and Medal, publication shall be made in three successive issues of the JOURNAL OF THE FRANKLIN INSTITUTE, stating that at the expiration of three months from the date of first publication, the Committee on Science and the Arts will recommend to the Committee on Minor Trusts of the Philadelphia Board of City Trusts, that it shall award the said premium and medal to the inventor, unless within that time satisfactory evidence shall have been submitted to the Committee on Science and the Arts of the want of originality in the supposed invention or improvement. In case no such objection to the final award of the premium and medal is made, the Secretary shall certify the recommendation of the award to the Committee on Minor Trusts of the Philadelphia Board of City Trusts.

HISTORY OF THE MEDALS.

The Elliott Cresson Medal.—Under date of February 18, 1848, Elliott Cresson, Esq., of Philadelphia, Pennsylvania, conveyed to Trustees, for the Franklin Institute, one thousand dollars of the six per cent. convertible loan of the President, Managers and Company of the Schuylkill Navigation Company—to hold the said sum and the interest to accrue thereon, for the following use and purposes:

1. The Trustees to keep the principal invested as it now is until it is reimbursed by the said Company, and immediately after such reimbursement to reinvest the said principal of one thousand dollars in such securities, bearing interest, as may by law be designated for the investment of trust funds. And from time to time, as the said principal sum may be reimbursed, to re-invest the same in like manner.

2. To cause suitable dies to be prepared for striking the gold medal out

of the first sufficient moneys received for interest on the said sum of one thousand dollars. The dies to bear the following devices and inscriptions: The obverse,—a medallion likeness of the said Elliott Cresson with inscription around the margin "Elliott Cresson Medal, A.D., 1848." Reverse,—around the margin, "Awarded by the Franklin Institute of Pennsylvania." The centre to be filled by engraving the name of the party to whom awarded and the year in which the award may be made.

3. After the said dies have been prepared, and paid for out of the money received for interest, the said Trustees to cause to be struck, from time to time, such number of gold medals as the interest received will pay for, and to deliver the same to the Treasurer of the Franklin Institute, to be by him delivered to such persons or parties as the said Franklin Institute, by any rule or regulation they may adopt, may have awarded the same. The said awards, however, to be in all instances made either for some discovery in the arts and sciences, or for the invention or improvement of some useful machine, or for some new process or combination of materials in manufactures, or for ingenuity, skill or perfection in workmanship.

The Howard N. Potts Medal.—Howard N. Potts of Philadelphia, Pennsylvania, died July 24, 1906, leaving a will in which he provided for the establishment of this medal as follows:

I give and bequeath to "The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts," and its successors, the sum of one thousand dollars, without deduction for taxes or charges; in trust to invest the same and apply the income thereof or such part or portion of it as may be adequate for the purpose, from time to time, to the purchase of a gold medal, to be awarded in the name of the said Franklin Institute for distinguished work in science or the mechanic arts.

The Edward Longstreth Medal of Merit.—In the month of May, 1800, Edward Longstreth, machinist and retired member of the Baldwin Locomotive Works of the City of Philadelphia, deposited with the Franklin Institute

in trust, a registered bond of the Baltimore Traction Company for the sum of one thousand dollars, for the founding and perpetuation of the Edward Longstreth Silver Medal; the interest accruing from said principal sum to be used in procuring and awarding said medals for the encouragement of invention, and in recognition of meritorious work in science and the industrial arts; the said awards to be made by the Franklin Institute through its Committee on Science and the Arts, under such rules as said Committee may adopt.

This donor further presented to the Franklin Institute twelve silver medals and the dies therefor designed and executed under the direction of a committee of the Institute with the approval of the donor.

The obverse of the medal bears the effigy of the donor, and is inscribed around the margin, "The Edward Longstreth Medal of Merit, founded 1890." On the reverse is inscribed around the margin, "Awarded by the Franklin Institute," the centre to be filled by the engraved name of the recipient, with the date and object of award.

On May 14, 1890, the Board of Managers of the Franklin Institute, by resolution, accepted on behalf of the Institute the gifts of the donor, and on September 17, 1890, the Institute, by resolution following, confirmed the acceptance:

"*Resolved*, That the Institute hereby confirms the action of the Board of Managers in accepting the gift of foundation of the Edward Longstreth Medal of Merit, and in expressing its grateful acknowledgments for the gift.

"*Resolved*, That the grant of the Edward Longstreth Medal, in accordance with the wishes of the donor, be entrusted to the Committee on Science and the Arts, subject to such conditions as the said Committee, with the approval of the Institute, may propose."

The Certificate of Merit.—At the stated meeting of the Institute, held on June 21, 1882, the following resolutions were adopted:

"*Resolved*, That the Committee on Science and the Arts of the Franklin Institute is hereby authorized to award, and issue to persons by said Committee adjudged worthy, a Certificate of Merit

for their inventions, discoveries or productions, which certificate shall read as follows:

"The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, awards to _____ this Certificate of Merit.

This award is made pursuant to the recommendation of the Committee on Science and the Arts.

Report No. ——— Approved, ——— 19

*Chairman of the Committee on
Science and the Arts.*

————— *President.*

[SEAL] ————— *Secretary."*

The John Scott Legacy Premium and Medal.—John Scott, chemist, late of Edinburgh, by his will made in the year 1816, bequeathed the sum of four thousand dollars in the funded three per cent. stock of the United States, to the corporation of the City of Philadelphia, directing that the interest and dividend to become receivable thereon should be laid out in premiums, to be distributed among ingenious men and women who make useful inventions, but no such premium to exceed twenty dollars, and that therewith shall be given a copper medal with this inscription: "To the most deserving."

The Select and Common Councils of the City of Philadelphia, by an ordinance passed February 17, 1834, vested the award of the aforesaid premiums and medals in the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts.

The Legislature of the State of Pennsylvania, by an Act passed and approved June 30, 1869, created a Board of Directors of City Trusts, to whom was referred the charge of administration of all estates dedicated to charitable uses.

The control of the John Scott Legacy Premium and Medal was (by the Act of 1869) transferred to the Board of Directors of City Trusts.

This Board, by a resolution passed April 12, 1882, referred the matter, with instructions, to its Committee on Wills' Hospital and Minor Trusts.

The Committee on Wills' Hospital and Minor Trusts, by a resolution passed April 12, 1882, resolved that "they will favorably receive the names of any person whom the Franklin Institute may, from time to time, report to the Committee on Minor Trusts as worthy of receiving the John Scott Legacy Premium and Medal."

The Franklin Institute, by a resolution passed June 21, 1882, accepted the above, and referred the duty of making examinations, etc., to the Committee on Science and the Arts.

FORM A.

THE FRANKLIN INSTITUTE

OF THE
STATE OF PENNSYLVANIA
FOR THE
PROMOTION OF THE MECHANIC ARTS.

(The following form must be filled-in, signed, and promptly returned to the Secretary of the Institute, at 15 South Seventh Street, Philadelphia, by the applicant for an examination and report upon an invention or discovery.)

In the matter of your application to the Franklin Institute for a consideration of your invention or discovery entitled _____

_____ the

following data are requested for the information of the Committees on Science and the Arts:

1. What is the specific purpose of the invention?
2. What is the condition of the prior art in this regard?
3. What improvement is claimed to be effected by the invention?
4. How is the improvement effected?
5. What patents, if any, have been issued for this invention?
6. What citations, if any, were made in this regard by the Patent Office before allowance of patent claims?
7. Is the invention now in actual use?
8. If so, since when?
9. Where may it be seen in operation?
10. Are you prepared to submit drawings of the apparatus or device?
11. Are you prepared to submit a model of the apparatus or device?

12. If the invention is a composition of matter, are you prepared to submit specimens of the ingredients and of the compound sufficient for the purpose of experiments?

13. If the invention is a chemical process, are you prepared to give a demonstration of the same?

FORM B.*

*This report is to be signed by all members of the sub-committee who participated in the investigation.

THE FRANKLIN INSTITUTE

OF THE
STATE OF PENNSYLVANIA
FOR THE
PROMOTION OF THE MECHANIC ARTS.

No. _____

REPORT OF SUB-COMMITTEE, dated _____

Investigating _____

TO THE COMMITTEE ON SCIENCE AND THE ARTS:

Your sub-committee appointed to investigate the above subject reports as follows:

In consideration of the { discovery
excellence of construction
ingenuity and novelty
or

of _____

your sub-committee recommends the award of _____ to

_____ of _____.

Respectfully submitted,

_____ Chairman.

FORM C.

THE FRANKLIN INSTITUTE

OF THE
STATE OF PENNSYLVANIA
FOR THE

PROMOTION OF THE MECHANIC ARTS.

HALL OF THE INSTITUTE,

Philadelphia, _____.

No. _____.

The Franklin Institute of the State of Pennsylvania, acting through its Committee on Science and the Arts, investigating _____

_____ reports as follows:

In consideration of the	{	discovery
		excellence of construction
		ingenuity and novelty
		or

of _____

the Institute recommends that the Philadelphia Board of City Trusts shall award the John Scott Legacy Premium and Medal—or—the Institute awards

the _____

to _____ of _____.

Adopted at the stated meeting of _____,
19—.

_____ *President.*

_____ *Secretary.*

Countersigned _____

*Chairman of the Committee on
Science and the Arts.*

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

Changes of Address.

DR. MORTON G. LLOYD, 215 South Oak Park Ave., Oak Park, Ill.
A. L. ADAMS, 721 Balboa Building, San Francisco, California.
WALTER E. DUNHAM, Supervisor, Motive Power & Machinery, care
C. & N. W. Ry., Winona, Minn.
MARTIN L. GRIFFIN, The Oxford Paper Co., Rumford, Maine.
SAMUEL E. DOANE, Drawer "N," Cleveland, O.
CARL G. BARTH, 1937 North Thirty-third Street, Philadelphia.
C. E. SARGENT, Marine Building, 152 Lake Street, Chicago, Ill.

OBITUARY.

Emanuel, Jonathan Manly, U. S. N., Retired, died at his residence, in Philadelphia, on Friday, June 24th, in his seventy-third year.

Mr. Emanuel was born in London, England, and came to this country in 1838. He was educated at Oakland Academy, Burlington, N. J., and in 1862 entered the naval service as third assistant engineer. He served with distinction throughout the Civil War and was promoted a number of times, retiring in 1891 with the rank of Passed Assistant Engineer.

During his service in the Navy, Mr. Emanuel invented an engine that is still used by the Government on several of its warships.

During the National Export Exposition, held at Philadelphia in 1899, he was one of the Judges. He became a member of the Franklin Institute in 1877, and has served on the Committee on Science and the Arts since 1887.

Converse, John H., died at Rosemont, Penna., on May 3, 1910.

He was born December 2, 1840, at Burlington, Vt. In 1857 he entered the University of Vermont and after his graduation, in 1861, became a member of the Editorial Staff of the Burlington, Vt., Times.

Three years later he went to Chicago and connected himself with one of the leading railroad companies of the West. After two years in Chicago, he became Chief Clerk of the Altoona shop of the Pennsylvania Railroad.

In 1870 Mr. Converse came to Philadelphia and entered the service of the Baldwin Locomotive Works, becoming a member of the firm three years later, and ultimately the leading spirit of that great industrial establishment.

He was for many years a director, or otherwise actively interested in a number of Banking and Trust Companies, and since 1899 he was a member of the Philadelphia Board of City Trusts. He served as a member of the Philadelphia Board of Education, as President of the Fairmount Park Art Association and was Trustee of the Presbyterian Hospital and the Pennsylvania Academy of the Fine Arts.

LIBRARY NOTES.

Purchases.

- ATTWOOD, E. L.—“War-ships.” A text-book, Ed. 3.
 BALDWIN, W. J.—“Heating.” Ed. 16.
 BALL, R. S.—“Natural Sources of Power.”
 BAXTER, W.—“Hydraulic Elevators.”
 BOTONE, S. R.—“Magnetos for Automobilists.”
 CARPENTER, R. C.—“Heating and Ventilating of Buildings.” Ed. 5.
 DOOLITTLE, C. L.—“Treatise of Practical Astronomy.”
 FOLWELL, A. P.—“Water-Supply Engineering.”
 FOSTER, H. A.—“Electrical Engineer’s Pocket Book,” Ed. 5.
 GERHARD, WM. P.—“Modern Baths and Bath Houses.”
 GERHARD, WM. P.—“Water Supply, Sewerage and Plumbing of Modern City Buildings.”
 HOBART and ELLIS.—“High-speed Dynamo Electric Machinery.”
 HOPWOOD, H. V.—“Living Pictures.”
 JACOBY, H. S.—“Structural Details or Elements of Design in Heavy Framing.”
 JOLY, J.—“Radio-Activity and Geology.”
 JONES, F. R.—“The Gas Engine.”
 KIMBALL and BARR.—“Elements of Machine Design.”
 LATTI, NISBET.—“American Gas Producer Practice.”
 LEVIN, A. M.—“Modern Gas Engine and the Gas Producer.”
 LEWIS, M. H.—“Waterproofing.”
 LYNDON, LAMAR.—“Development and Electrical Distribution of Water-Power.”
 MACLAURIN, R. C.—“Light.”
 MEHRTEUS, A. C.—“Gas Theory and Design.”
 MOORE, W. L.—“Descriptive Meteorology.”
 MOLITOR, D. A.—“Hydraulics of Rivers, Weirs and Sluices.”
 POTAMIAN and WALSH.—“Makers of Electricity.”
 SCHUYLER, J. D.—“Reservoirs for Irrigation, Water-Power and Domestic Water Supply,” Ed. 2.
 SCRIPTURE, E. W.—“Researches in Experimental Phonetics.”
 SOPER, G. A.—“The Air and Ventilation of Subways.”
 SPITTA, E. J.—“Photomicrography.”
 WILSON, W. L.—“Elements of Railroad Track and Construction.”
 WOOD, DE VOLSON.—“Thermodynamics, Heat Motors, and Refrigerating Machines,” Ed. 8.

Gifts.

- Societe Ingenieurs Civils France. Annuaire. Paris, 1910.
 Societe Internationale des Electriciens. Annuaire. Paris, 1910.
 Maryland Geological Survey, vols. 7 and 8, 1908-09. Baltimore, 1909.
 Maryland Weather Service, vol. 3. Baltimore, 1910.
 Royal Society of Canada, Proceedings and Transactions 1909.
 Nova Scotian Institute of Science Proceedings and Transactions, vols. 11 and 12, Halifax, 1908.
 McGill University and College Calendar, 1910-11, Montreal, 1910.
 "Mechanics of the Earth's Atmosphere," By Cleveland Abbe. Smithsonian Institute, Washington, 1910.
 Engineer's Directory for 1909. London, 1910.
 Interstate Commerce Commission Report, 1909. Washington, 1910.
 Massachusetts Railroad Commissioners Annual Report, 1909. Boston, 1910.
 Michigan Department of Labor Report for 1909. Lansing, 1910.
 Victorian Institute of Engineers Proceedings, vol. 10. Melbourne, 1910.
 West Virginia Mines Department Report. Charleston, 1909.
 Canadian Mining Institute Journal, 1909. Montreal, 1910.
 Drexel Institute Year-Book, 1909-1910. Philadelphia, 1910.
 K. K. Geographische Gesellschaft in Wien. Mitteilungen, vol. 52, 1909, Wien, 1909.
 Leland Stanford Junior University Register, 1909-1910.
 Ontario Agricultural and Experimental Union Report, 1909. Toronto, 1910.
 Ontario Fruit Growers' Association Report, 1909. Toronto, 1910.
 Ohio Mechanics Institute Annual Catalogue, 1910. Cincinnati.
 Connecticut Special Laws, vol. 15, 1909. Hartford, 1910.
 Connecticut Labor Bulletin. Hartford, 1909.
 Canadian Society of Civil Engineers, vol. 23, 2, 1909. Montreal, 1910.
 Water Supply Commission of Penna. Report for 1908. Harrisburg, 1910.
 American Institute Mining Engineers, vol. 40, New York, 1910.
 Vermont Insurance Report. Bellows Falls, 1909.
 Wisconsin Agricultural Experiment Station 25-26. Annual Reports, 1908-09, Madison.
 United States Brewers Association Year-Book, 1910. New York, 1910.
 United States Civil Service Commission, 26th Report. Washington, 1910.
 Statistical Abstract of United States, 1909. Washington, 1910.
 Commerce and Navigation of the United States, 1909. Washington, 1910.
 Illinois Geological Survey Bulletin, Nos. 12, 13, 14. Urbana, 1909.
 Massachusetts Board Gas and Electric Light Commissioners Report, 1909, Boston.
 Contributions from the Jefferson Physical Laboratory of Harvard University 1909.
 Waltham City Documents, 1909. Waltham, 1910.

SECTIONS

in Mining and Metallurgy.—The stated meeting of the Section was held in the Hall of the Institute on Thursday, May 19, 1910, at 8 P.M., with Prof. E. Outerbridge, Jr., in the Chair. The meeting was attended by twenty-five members and visitors. The minutes of the previous meeting were read and approved.

Dr. Edgar T. Wherry of Lehigh University read a paper entitled "The Copper Deposits of Franklin-Adams Counties." The geology and the igneous rocks of the region were described. An account was given of the copper minerals and their mode of occurrence. Native copper predominates, although carbonates, silicate and sulphide of copper also occur. The source of the copper and the mode of formation of these deposits were discussed. The lecture was illustrated with lantern slides and with a specimen of the ore.

The paper was discussed by Professor Outerbridge, Dr. Goldsmith, Dr. Wherry and others, and was referred to the Committee on Publications.

A vote of thanks was tendered the speaker. The Meeting then adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

Artificial Silk. FRANCIS J. G. BELTZER. (*Moniteur Scientifique*, xxiv, 821.)—The manufactories of artificial silk with a nitro-cellulose base, are constantly increasing their production, and the number of factories also steadily increases. Besides the long-established factories in France, Belgium, Germany and Italy, others have been founded in Russia, Hungary, Austria, the United States and elsewhere.

The production of cupro-ammoniacal silk is also greatly enlarging. The factories of Glanzstoff silk produce about six million pounds of textiles with a cupro-ammoniacal-cellulose base. Viscose silk is developing strikingly, producing about 2 million pounds.

In England a plant for the production of patent lustre-silk has been installed at a cost of \$250,000. In Germany, Bohemia and the United States many factories have started. The old methods of production are continually developing and perfecting the tenacity and elasticity of the thread, both in the dry and moist condition. Cellulose, as pure as possible, is the base for all these many manufactures.

PUBLICATIONS RECEIVED.

North Carolina Geological and Economic Survey. Bulletin No. 21. The Gold Hill Mining District of North Carolina. By Francis Baker Laney. 137 pages, plates, maps, 8vo. Raleigh, State Printer, 1910.

North Carolina Geological and Economic Survey Economic Paper No. 15. The Mining Industry of North Carolina during 1907 with special report on the mineral waters. By Joseph Hyde Pratt Ph.D. 176 pages, plates, maps, 8vo. Raleigh, State Printers, 1908.

Directory of Metallurgical and Chemical Material, 1910. Second Edition. 219 pages, 12mo. New York, Metallurgical and Chemical Engineering. Price, paper, 50 cents.

Standard Specifications for Creosoted Wood-block Pavement. Requirements and Tests for Quality of Paving Brick. By J. W. Howard, consulting engineer. 4 leaflets, quarto. New York City, author, 1910.

Carb-ox Company. Catalogue of gas analysis instruments and allied specialties. 16 pages, illustrations, narrow 8vo.

U. S. Coast and Geodetic Survey. Results of observations made at the coast and geodetic survey magnetic observatory near Honolulu, Hawaii, 1905 and 1906, by Daniel L. Hazard, Computer, Division of terrestrial magnetism. 112 pages, illustrations, quarto. Washington, Government Printing Office, 1910.

U. S. War Department. Annual reports, 1909. 9 volumes, plates, maps, tables, 8vo. Washington, Government Printing Office, 1909. Contents: Reports of the Secretary of War, Chief of Staff, Adjutant-General, Inspector-General, Judge-Advocate General, Quartermaster-General, Commissary-General, Surgeon-General, Paymaster-General, Chief Signal Officer, Chief of Coast Artillery; Departments of the East, of the Gulf, of the Lakes, of the Missouri, of Dakota, of Texas, of the Colorado, of California, of the Columbia; Philippine Division, Department of Luzon, Department of the Visayas, Department of Mindanao, Army of Cuban Pacification, Military Academy, Military Parks, Chief of Engineers, Chief of Ordnance, The Philippine Commission, Governor of Porto Rico; Acts of First Philippine Legislature.

Popular v. Delegated Government. Oregon has the best system of popular government in the world to-day—The Australian ballot—Registration of voters—Initiative and Referendum—Direct Primary—Corrupt practices act—Recall—An absolute government by the people. Speech of Hon.

Jonathan Bourne, Jr., of Oregon in the Senate of the United States, Thursday, May 5, 1910. 16 pages, 8vo. Washington, Government Printing Office, 1910.

Canada Mines Department, Mines Branch. Annual report of the division of mineral resources and statistics on the mineral production of Canada during the calendar 1907 and 1908. John McLeish, B.A., Chief of the Division. 286 pages, 8vo. Ottawa, Government Printing Bureau, 1910. Price in paper 15 cents.

Argentina, Centenario de la Republica. Exposicion internacional de ferrocarriles y transportes terrestres, Buenos Aires Mayo a Noviembre, 1910. Circular No. 19. Idioma Ingles. 12 pages, illustrations, quarto. Buenos Aires, 1910.

Der Verein Deutscher Ingenieure und seine Arbeiten. Herausgegeben aus Anlass der Weltausstellung in Brüssel, 1910. 47 pages, illustrations, narrow 16mo. Berlin, Society, 1910.

Turner-Fricke Manufacturing Company. Catalogue of Gas and Gasoline Engines. 26 pages, illustrations, narrow 12mo. Pittsburg, Penna. (n. d.)

U. S. Navy Department. Report of Board on Comparative Trials of the Scout Cruisers Birmingham, Salem, Chester. 90 pages, 8vo. Washington, Government Printing Office, 1910.

Alpha Portland Cement Company. Alpha Portland Cement for Eternity. 48 pages, illustrations, 4to. Easton, Penna., Alpha Portland Cement Co., 1910.

Contractors Supply and Equipment Co.' Catalogue. 44 pages, illustrations, oblong quarto. Denver, Col., Company, 1910.

Chrome-Steel Permanent Magnets. W. BROWN. (*Sci. Proc. Roy. Dublin Soc.*, xii, 349.)—Assuming, as stated by Mme. Curie, that small quantities of silicon have little or no effect on the magnetic properties of steel, the magnetic moment per gram is found to increase uniformly with the increase of chromium, until a maximum is reached with 2.5 per cent. of chromium, from which it falls as the chromium reaches 3.5 per cent. Any further addition of chromium does not affect the magnetic moment. The maximum points are liable to disturbance through varying quantities of carbon, silicon, manganese, tungsten and copper, which also affect the retentiveness of the magnets.

CURRENT TOPICS

Gredag. (*Iron Age*, lxxxv, 22.)—Gredag is the trade name adopted by the Internat. Acheson Graphite Co. for its graphite grease, in order that it may be distinguished from grease products which contain impure natural graphite. The graphite, blended with a high-grade grease, in Gredag is an electric furnace product, as pure as can be made. All the merits of both graphite and grease are combined in Gredag, making a lubricant of high quality and value. This concern now produces three lubricants containing deflocculated Acheson graphite, Aquadag, Oildag and Gredag.

The Electric Drive in Industrial Establishments. (*Eng. Record*, lxi, 21.)—The value of the electric drive was clearly shown after the explosion of four out of the eight 400 h.p. boilers in the plant of the Pabst Brewing Co., at Milwaukee, which is operated electrically throughout. To shut down the plant would involve a heavy loss, for unless the processes are carried on with regularity, the product at various stages becomes spoiled. In this case it was possible to make arrangements with the Milwaukee Electric Railway and Power Company for 600 k.w. Three transformers were put in place in a few hours, and in a short time the operation of the brewery was resumed, saving a considerable direct loss and much inconvenience in other respects.

Behavior of Fluorides in the Preservation of Wood. R. NOWNY. (*Oester. Chem. Zeit.*, 1910, xiii.)—Experiments made by various methods on the impregnation of wood (telegraph poles, etc.), with solutions of fluorides, with special reference to selective absorption, show that when wood is steeped in a solution of zinc hydrogen fluoride ZnF_2 , 2HF , containing free hydrofluoric acid the solution is absorbed as a whole, no change in composition being observed. The surface of the treated wood becomes brown, but its quality does not suffer in any way. If, however, the solution be forced through the green wood by hydrostatic pressure, as in Boucherie's method, the ratio of zinc to fluorine in the liquor becomes greater, showing that fluorine is extracted from solution by the wood; and that free hydrofluoric acid is extracted to a greater extent than the combined acid.

Magnetic Properties of Electrolytic Iron and Some Steels. C. F. BURGESS and J. ASTON. (*Met. and Chem.*, 1910, viii.)—Data are given on a series of tests on the magnetic quality of various electrolytic irons, both as deposited and after subsequent melting

and forging. A considerable variation of quality existed in the forged bars before annealing, not accountable for by differences of purity, but when they were heated to 675° C. and slowly cooled, a practically uniform high quality resulted. Annealing at 1000° C. improved the quality for the lower ranges of magnetizing force to a certain extent, but was less satisfactory than annealing at 675° C. Quenching from 900° C. caused slight deterioration for all magnetizing forces. Data are also given of similar tests on various commercial steels, showing that refining improves the magnetic qualities, but that the amounts of impurities generally met with in commercial practice do not result in serious deterioration of the quality. The heat and mechanical treatment is, however, of extreme importance and a comparatively low-grade steel may be greatly improved by judicious annealing.

International Geological Congress. (*Iron Age*, lxxxv, 22.)—The eleventh session of this Congress will be held at Stockholm, Sweden, on August 18 to 25, 1910. The general secretary is Professor J. G. Andersson, Stockholm. A number of trips have been arranged to Swedish iron mines and iron and steel works. The executive committee, with the assistance of geological surveys and eminent geologists from various countries, is compiling a summary of the iron ore deposits of the world, designed to show the amount and distribution of the world's supply of iron ore. The reports from the different countries, in the original languages, are collected in two quarto volumes, containing 1100 pages. Professor J. F. Kemp, Columbia University, New York, furnished the report for the United States.

Contraction of Metals and Alloys. F. WUST. (*Metallurgie*, vii, 321.)—For the measurement of contraction the author has designed an apparatus, which eliminates the uncertainty of the levers used to magnify the contraction in earlier designs. The metals are cast into bars of 500 mm. length in a mould, into the ends of which project stout iron wires ending in coils which become embedded in the cast bar. The other ends of the wires are connected to pistons operating in water-tight cylinders. The two cylinders are filled with distilled water and connected to a capillary measuring gauge. Changes in the volume of the bar are indicated by the movement of the liquid in the tube, which is read by one observer, while another observer takes a cooling curve by means of a thermocouple placed in the centre of the bar. The results are plotted in the form of temperature-contraction curves, which are compared with the "inverse rate" cooling curves. Experiments were conducted with the metals lead, tin, zinc, aluminum, copper, bismuth and antimony, and a number of their technically important alloys. The results lead to the conclusions that: (1) alloys whose components are mutually insoluble in the solid contract less than either

of the constituents, the eutectic alloy having the lowest coefficient of contraction; (2), alloys consisting of one or more solid solutions contract more than the constituent metals; and (3) there is no law connecting contraction and melting point, either for metals or alloys.

Carbon Bisulphide as a Gaseous Product. J. DEWAR and H. O. JONES. (*Proc. Roy. Soc.*, A83, 1910.)—The authors find that carbon bisulphide changes to a gaseous product condensable and explosive near the temperature of liquid air. When a rapid current of carbon bisulphide vapor, at a pressure of about 1 mgm., is submitted to the action of the silent electric discharge, it is partially decomposed into sulphur and a new volatile sulphide of carbon, probably carbon monosulphide; this is condensed, along with the unchanged carbon bisulphide, at the temperature of liquid air, and polymerizes at a slightly higher temperature with explosive violence, to give a brown solid, which is apparently identical with the known polymeric form of carbon monosulphide. The new gas is not completely destroyed by passing the gaseous mixture from the ozonizer rapidly through a short length of red-hot tube; it quickly polymerizes at the ordinary temperature, even at low pressures, and in the presence of a large excess of carbon bisulphide.

Gases Containing Helium from the German Potash Deposits. E. ERDMANN. (*Ber.*, 1910, xliii.)—In one of the Leopoldshall workings a blower of inflammable gas has been issuing at a depth of 450 meters since August, 1904. The gas contains 83.6 per cent. of hydrogen, 4.4 of methane, and 12 of other gases, including helium and neon. The helium greatly preponderates over the neon, but the two together form about 0.17 per cent. of the original gas, or nearly 1 per cent. of the gas after the removal of the hydrogen. The author attributes the existence of the helium to the degradation of radium salts originally contained in the waters of the sea which furnished the deposits, and he regards the hydrogen as resulting from the radio-active decomposition of water, the equivalent oxygen having disappeared in converting ferrous into ferric salts in the carnallite.

Preparation of Zirconium. L. WEISS and E. NEUMANN. (*Zeit. anorg. Chem.*, lxx, 248.)—Electrodes of zirconium were made by compressing Zr. powder into sticks and heating it in hydrogen, and used in an arc furnace filled with neutral gas. The metal obtained had a brassy color, which turned blue on heating, was very brittle and could be crushed in a mortar. Its hardness is 7 to 8, and its density 6.4 at 18° C. Its specific heat is 0.0804 and the heat of combustion 1959 cal. per gramme. Powdered Zr. is easily ignited, the compact metal is harder to ignite. Zr.H_2 was made by heating the metal in hydrogen. When burned in oxygen Zr_2O_3 was formed.

A Method of Renewing Carbon Filaments. SCHMITTUTZ. (*Electro. tech. Zeit.*, xxxi, 355.)—The lamp is supposed to have burned long enough to blacken the bulb, but not to have broken the filament. The top of the lamp bulb is opened, and a tube fused to it at this point. The bulb is then sufficiently heated to burn off the carbon deposit. A small amount of some suitable hydrocarbon is then introduced into the bulb and a vacuum produced. Current is passed through the filament and carbon is thus deposited in a manner similar to that adopted in the ordinary flashing process. The cost is said to be about 5c. per lamp.

Glass and Porcelain. O. PARKERT. (*Sprechsaal*, 1910, xliii.)—New methods of decorating glass and ceramic ware have been opened up by the use of reduction colors. If a silver mirror be formed by dipping a piece of ware in a solution of a silver salt and reducing with sugar and tartaric acid, many varieties of red and blue can be obtained by treating it with potassium permanganate solution for varying periods. If the permanganate be applied only in places, iridescent effects are obtained. Similar colors are given by gold, which is best applied in the form of chloride, dissolved in a solution containing 10–15 Gm. of sodium chloride per litre. The ware should be dried in a dark room. It is overglazed and fired in a muffle. The color effects are quite permanent.

Intrinsic Brightness of the Sun. C. NORDMANN. (*Comptes rendus*, cl, 448.)—The effective temperature determined with the author's pyrometer was found to be about 5320° C. absolute. Now the brightness of an incandescent body emitting white light varies sensibly as a function of the temperature, and this law has been verified by comparison with numerous terrestrial light sources. Taking into consideration the absorption of the solar atmosphere, the effective temperature of the photosphere is probably about 6450° C. absolute. The corresponding brightness of the mean effective layer is then about 319,000 decimal candles per square cm. The solar surface is thus considered to behave very much like a black body, and to have an emissive power of nearly unity.

Metallic Tungsten. L. WEISS, A. MARTIN and A. STIMMELMAYE. (*Zeit. anorg. Chem.*, lxxv, 279.)—Experiments made on the reduction of wolframite, barium and calcium tungstates, tungsten oxide and tungsten sulphide by means of aluminum, zinc, magnesium and carbon, showed that none of them would give the pure reguline product desired. Experiments are described in which tungsten powder was melted in a vacuum furnace by the magnetic arc. The electrodes were of tungsten powder, strongly compressed into sticks and heated in hydrogen to make it a conductor. The arc was deflected into a zirconia crucible, into which the molten metal dropped as the ends of the electrodes fused off. The proper-

ties of the metal varied with the rate of cooling; when cooled rapidly it was brittle and had a granular fracture, a hardness of 7.5 and its density was 18.71 to 18.74; when cooled slowly it was malleable, had a conchoidal fracture, a hardness of 6.5, and its density was 18.72 to 18.74. The specific heat was 0.0358 and the heat of combustion 1047 cal. per gramme.

The Mother Lode Mine in British Columbia. R. H. ALLEN. (*Eng. Min. J.*, lxxxviii, 1101.)—The mine is situated at Deadwood Camp and is connected with the smelter by a spur of the Canadian Pacific Railway. The ore is from 30 to 200 feet in width, and belongs to the so-called "magnetic" type; it includes the minerals magnetite, chalcoppyrite and pyrite, with a little blende, galena, pyrrholite and occasionally a little arsenopyrite; intermixed with calcite, actinolite, garnet, epidote and quartz. The most valuable metal is the copper, but the ores will average more than \$7.00 per ton in gold and silver. Tests show that the ores with 2 per cent. copper carry the most gold, while those with as high as 30 per cent. copper carry no gold. There is no limestone within the ore body. The output varies from 1000 to 1600 tons daily. The labor cost per ton of ore does not exceed 65 cents.

Gas from Heated Metal. G. BELLOC. (*Comptes rendus*, cxlix, 672.)—When steel is heated in a vacuum, gas is evolved at 150° C., and at 400° C. the volume evolved becomes considerable. Gas can not be completely driven out from steel by long continued, strong heating; rather the metal must be considered as a practically inexhaustible gas reservoir.

A New Sclerometer. A. L. PARSONS. (*Am. Jr. Sci.*, xxix, 162.)—This new instrument differs from older ones in that the force necessary to make the scratch is measured by a spring and not by weights. It must, of course, be calibrated, that is, the force necessary for bending the spring must be determined in weights. So far the instrument has been applied only to polished metal and glass surfaces and not to minerals. The advantages claimed are rapidity of observations, compactness and cheapness.

The New Nitrogen Fertilizers. H. VON FEILITZEN. (*J. Soc. Chem. Ind.*, xxviii, 723.)—Since 1904 extensive experiments have been made with fertilizers obtained from the atmosphere by the help of the electric furnace. These experiments were made partly in pots and in wooden boxes, sunk in the soil, and also field experiments at Flahult. The plants grown were oats, potatoes and hemp. The effect of calcium nitrate was at least equal to that of sodium nitrate in all the experiments. In the case of oats the yield of grain in relation to straw was increased more by calcium nitrate than by sodium nitrate. The hygroscopicity of the calcium nitrate

is its only drawback. Experiments were also made with calcium cyanamide. Its decomposition in the soil produces compounds possibly injurious to vegetation. Comparative experiments showed this fertilizer should always be applied some time before sowing the seed, to avoid injury during germination; and as a top dressing it must always be applied very early, that the plants may not suffer. In wet seasons calcium cyanamide seems to give better results than in dry seasons.

Luminous Efficiency of the Firefly. H. E. IVES and W. W. COBLENTZ. (*Bull. Bur. Standard*, vi, 321.)—By photographing the spectrum of the local firefly, *Photinus pyralis*, the radiation from it was shown to be limited to the yellow-green region, λ 510-670. There is a maximum of intensity at 570, but the band is not composed of fine lines. The computed luminous efficiency (light radiation) is 96.5 per cent., as against 0.4 per cent. for the carbon glow lamp.

Concrete Floors in Vessels. (*Eng. Record*, lxi, 25.)—Concrete floors were tried in a number of wooden vessels carrying ore and coal on the Great Lakes as a substitute for wooden floors, which suffer severely from the clam-shell buckets. The concrete floors are said to stand the wear very well.

Gaseous Suspensions. M. DE BROGLIE. (*Physik. Zeit.*, xi, 33.)—Some kinds of smoke observable in gases consist of fine particles, observable in the ultra-microscope, of radius between several μ μ and several hundred μ μ . These show Brownian movements capable of being photographed and agreeing with a formula of Einstein's. In this respect they are surprisingly like particles in liquids. They differ electrically at times in being either negative or positive or neutral, while those in liquids are never neutral.

Copper Clad Steel. W. TATTIN. (*J. Ind. Eng. Chem.*, i, 670.)—Numerous attempts have been made to cover steel with a coat of copper of any desired thickness and to weld the two metals so firmly that the combination could be submitted to any of the usual methods of working metals without destroying the integrity of the weld. This desired result was only attained by the process to be described. Steel of any description, composition or shape is rolled into rounds and cut into 26-inch billets, to make wire rods, and is sand blasted and pickled to remove scale. The billet, drilled and tapped at each end, is hung by a rod and bushing screwed into one end in a pre-heater and brought to a red heat. The billet is then drawn into a tube by means of a rod screwed into the top of the bushing. This rod slides in the centre hole of a three-jawed chuck, which holds the tube and centres the billet in it. A steel flange is then screwed on the bottom of the billet, thus forming with

the tube a mold in which the billet is the core. The mold and billet are now carried to a pot of specially prepared copper, in a super-molten condition. The billet, and its attached flange, are inserted in the copper and kept there long enough to wet the surface of the steel and to form an alloy film. The billet is then drawn from the copper into the tube, and the billet and its mold are carried to a second pot containing commercially pure copper, in which the final coat of copper is applied. The mold is filled with copper and after withdrawal when the copper has solidified, the chuck, rod, and flange are unscrewed. The tube and its contents are then placed in a ram and the copper-clad steel billet is pushed out of the mold. The billet is now given a washing heat and is rolled to the desired size. The proportional areas of the copper and steel remain practically constant during the reduction in size. The tensile strength of the copper-clad steel is equal to, and sometimes greater, than that of a steel of a similar composition, but with a sectional area equal to that of the clad metal. There are many uses for copper clad steel; the most obvious is as a wire for electrical and mechanical purposes. The breaking weight and elastic limit of a No. 10 copper wire are respectively 530 and 293 lbs., while those of a No. 14 copper clad is 760 and 320 lbs. The one weighs 116 lbs. per mile and the other 61 lbs. Comparing copper clad with galvanized iron telephone wire, a much smaller size of copper-clad may be used for the same ohmic resistance. The resistance of copper-clad steel is equal to that of copper, and is immeasurably greater than that of steel.

Resinite. (*British Jrnal of Photo.*, June, 1910.)—The American Consul at Chemnitz mentions a new substance, invented in Germany, for replacing celluloid, ivory, etc., known as resinite, for which a number of applications has been found. It is produced in a variety of modifications by the union of formaldehyde and phenol, with certain metallic salts. In one form it appears like ordinary resin, but in another form can be poured as liquid into moulds. When cold it is transparent, with a ruby tint, infusible and unaffected by chemical reagents. It is well adapted for making ornaments, imitation jewelry, and most purposes where enamel or enamel varnish is employed. It has the great advantage, compared with celluloid, of being non-combustible. [This is evidently "Backelite."—Obs. See JOUR. FRANKL. INST., clxix, 55.]

Metallic Carbonyls. L. MOND, H. HIRTZ, and M. D. COWAP. (*Trans. Chem. Socy.*, 1910, xcvi, 198.)—Experiments on the action of carbon-monoxide, under high pressure and at temperatures up to 450° C., upon finely divided (pyrophoric) metals, have led to the preparation of a new cobalt carbonyl, $\text{Co}(\text{CO})_3$, and molybdenum and ruthenium carbonyls. They all have very similar chemical properties: they decompose, when heated, into carbon mon-

oxide and the respective metals, which are deposited as mirrors, and they are not attacked by non-oxidising acids, though quickly dissolved by oxidising acids, and especially by aqueous solutions of the halogens, with the evolution of carbon monoxide. They are more or less soluble in the usual organic solvents, but are insoluble in water. Attempts to prepare manganese, chromium, tungsten, palladium and rhodium carbonyls have been unsuccessful.

The Passage of Vapors Through Glass. C. ZENGHELIS. (*Z. Phys. Chem.*, xxxii, 425.)—After his earlier observations had been criticised, the author repeated them and still finds that silver foil inclosed in a vessel of thin glass, from which the air has been partially exhausted, is attacked when the vessel is surrounded by another containing iodine crystals and closed with paraffin wax. He shows that the effect cannot be attributed to impurities in the atmosphere of the surrounding vessel, or to impurities in the paraffin. He gives data of experiments, one of which showed a decided loss in weight (15.7 m. grms) of a vessel containing 0.8 c.c. of bromine after standing 117 days. The facts that the action on the silver is local, and that the phenomenon varies with different vessels, lead the author to assume the existence of invisible pores through which gases may pass, as a frequent occurrence in thin glass vessels.

Alloys of Titanium and Silicon. (*Soc. Chem. Ind.*, xxix, 10.)—The Titanium Alloy Manufacturing Company have patented a process for producing such alloys, containing from 20 to 75 per cent. of silicon and from 5 to 70 per cent. of titanium. Silver sand is mixed with rutile or titanium oxide in the proportion desired and powdered carbon added so that two atomic weights of carbon are present for each molecular weight of silica or titanium oxide. The whole mixture is then reduced in an electric furnace of the arc type. One electrode is the graphitic interior of the furnace itself, the other is vertically movable in a central cavity. At the close of the reaction the fused alloy is withdrawn through a tap-hole. By adding a definite proportion of scrap iron to the charge, ferro-silico-titaniums are obtained. Similarly cupro-silico-titaniums can be produced.

Commercial Rust Proofing. (*Iron Age*, lxxxv, 21.)—The Bradley process of rust proofing is a hydrogen gas treatment. The article to be rust proofed is placed in a muffle, where it comes in contact with hydrogen gas and other materials necessary to the process and is then subjected to heat. This changes the surface, forming an alloy which resists the action of oxygen in air or water. The process can be used on bolts, nuts, or other threaded articles, as it causes no interference with the threads, as plating does. In addition to the rust proofing, the treated articles are benefited by

the careful cooling, which anneals them. The process cannot be used on hardened or tempered pieces. The color obtained is a dark, rich, blue-black, well adapted for builders' hardware, or any highly finished articles.

The First Girod Furnace in this Country. (*Iron Age*, lxxxv, 21.)—The Simonds Manufacturing Company, Fitchburg, Mass., is installing a Girod electric furnace in the crucible steel department of its Chicago plant. At Lockport, electric furnaces of larger size than the experimental one will be installed if the results at Chicago meet expectations. The Girod furnace is in use in numerous European works, their capacities ranging from two to twelve and one-half tons.

Thermal Conductivity of Fire-Clay. J. K. CLEMENT and W. L. EGG. (*Eng. Rec.*, lxi, 24, 754.)—These gentlemen investigated the thermal conductivity of fire-clay, to obtain information concerning the loss of heat through the walls of boiler furnaces. A resistance coil was inserted in a fire-clay cylinder about 16 inches long and 4.8 inches in diameter and provided with a hole about 1.4 inch in diameter for the coil. Four small longitudinal holes were made for the insertion of thermo-couples for measuring the temperature. The test cylinder was then inserted in a larger fire-clay cylinder in order to maintain higher temperatures in the former and a more uniform radiation from it. The ends were covered to prevent loss of heat there. The electrical apparatus was arranged so that a current could be kept constant within a variation of 0.1 ampère for several hours. Twelve cylinders were tested, embracing three varieties of fire-clay. The conductivity ranged from 0.00221 to 0.00362, averaging 0.00267.

Influence of Boiler Incrustations. G. REUTLINGER. (*Zeit. des Verein deutscher Ing.*)—The effect of incrustations in retarding the transmission of heat has been greatly overestimated; yet they may cause dangerous overheating of the plates. An incrustation $\frac{1}{4}$ inch thick may cause as much as 20 to 30 per cent. loss of heat according to the temperature of the firing gases. Oil or fat causes greater losses. A coating of tar, $\frac{1}{8}$ inch thick, caused a loss of 30 to 45 per cent. If the transference of heat is effected by contact and not by radiation, the losses caused by incrustation, when the heating is done by hot gases, may not be more than one-third the above amounts, but they may reach 70 to 80 per cent. when hot water or saturated steam is the source of heat. In such cases, e.g., steam heated evaporators, brewing coppers, etc., incrustations should be carefully avoided. When the temperatures of the heating medium and of the material heated do not remain constant, the following conclusions are reached. 1. *Heating medium constant, heated fluid variable.* For apparatus of moderately large size and not too

heavily forced, the loss may reach 15 to 30 per cent.; for smaller heating surface, or rapid circulation it may be 50 per cent. *Heating medium variable, heated fluid constant, e.g.,* boilers. The loss may amount to about 7 per cent. if contact heating alone be considered, or 5 per cent. with contact heating and radiation. *Both heating medium and heated fluid variable.* Saturated steam losses of 25 to 30 per cent.; heated by gases or super-heated steam, losses of only 5 to 15 per cent.

Development of Silver Bromide-Gelatin Plates in Hot Countries. L. J. BUNEL. (*Bull. Soc. Franc. Phot.*, i, 174.)—In developing gelatin-bromide plates in hot climates it is preferable to use either diaminophenol in acid solution, or metol-quinol in presence of acetone, and in absence of alkali, hydroxide or carbonate. The addition of potassium or sodium sulphate to the developer has been found to be the best means of making the gelatin insoluble and preventing "frilling." To avoid the production of bacteria during the final operations, they should be conducted as quickly as possible; antiseptics, such as formaldehyde, etc., are ineffective. Suitable formulæ are given for making up diaminophenol and metol-quinol developers and a combined fixing and hardening bath, containing potassium meta-sulphite and chrome-alum thiosulphate, and in addition 0.5 per cent. of potassium cyanide which prevents the precipitation of sulphur.

Increasing the Sensitiveness to Light of Asphaltum. G. VALENTA. (*Phot. Corresp.*, xlvii, 238.)—Asphaltum is heated, on a water bath, with 6 to 8 per cent. of its weight of sulphur chloride, diluted with four or five volumes of carbon bisulphide. When the evolution of hydrochloric acid has ceased, a portion of the solvent is distilled off and the residue diluted with benzene: the solution is now coated on metal plates. The plates thus formed are practically as sensitive as those coated with bichromated albumin.

Absorption of Barium by Plants. H. COLIN and J. DE RUFZ. (*Comptes rendus*, cl, 1074.)—Pease germinated in distilled water and then transferred to a very dilute solution of barium nitrate continued to grow and barium was absorbed. A dry root weighing 0.93 Gm. gave 0.146 Gm. of ash which yielded 0.015 Gm. of barium sulphate.

A Safe for Radium. (*The Times*, May 31, 1910.)—A safe has been made by Messrs. Chubb & Sons for the British Radium Corporation. It is constructed from the designs of the technical advisers to the Corporation, especially for the storage and protection of radium. Though only about 3 feet high it weighs one and one-half tons. It is constructed with an interior shell of 3-inch lead and an outer case of 3-inch steel. It is provided with a circular

lathe-turned door, which has a "dead" fit, and an ingenious contrivance for immediately remedying any wear and tear from opening and shutting. To prevent loss of emanations when the door is opened, two valves are fixed in the door, through which tubes of mercury are passed to collect and store the emanations.

Three-Color Photographic Process. R. BERTHON, France.—A patent has been secured by M. Berthon for this process. Photographic plates or films are prepared, having on one side a panchromatic emulsion, and on the other side a series of very small, transparent, spheroidal grains or cylindrical bands, close together, which are formed by embossing a gelatin or celluloid film. Plates made in this way are exposed with the emulsion farthest from the lens, behind an objective in which is fixed a screen composed of the three fundamental colors. The resulting negative is reversed, and may then be projected through the objective and screen, giving a colored projection. The grained or embossed screen acts as a series of lenses in front of the emulsion, causing the separation by refraction of the images of the screen projected in microscopic condition at points close together on the sensitive film; the result is similar to that obtained by a grained or lined screen, except that in this process more light passes to the emulsion.

Camphor Monopoly in Japan. (*Zeit. Angew. Chemie*, xxiii, 736.)—The Japanese camphor monopoly tried to control the market by increasing the price from 65 cents in 1903 to \$1 in 1906. The production of camphor was stimulated by giving the planter a higher price and by planting new trees to the number of 28 millions. After the introduction of German artificial camphor, and the revival of the Chinese production, the Japanese monopolists recognized that they could not dictate terms. The price was greatly reduced, and since 1908 Japanese camphor was sold in London and New York at \$34 to \$35 per 112 pounds. To reduce the loss part of the camphor oil was sold to the refineries and the separated camphor taken back, whereas previously the refiners had received the residues (red and white oils and tar) as payment for the refining. In Formosa the cheaper cost of production renders the conditions more favorable. Only a small quantity of camphor is used in Japan, though as the Japanese are commencing the manufacture of celluloid, the consumption will increase.

Accumulator Plates. F. FISCHER. (*Z. Elektrochem*, xvi, 355.)—The large unprepared lead plates are first oxidized so as to form a coating of lead monoxide by making them anodes in the electrolysis of a 10 per cent. solution of sodium phosphate at 80° C., between cathodes of the same area. The E. M. F. is allowed to rise during the process from 2.2 to not more than 2.6 volts. In 24 to 36 hours the plates are covered with a firm coating of lead

monoxide. This is then reduced to spongy lead by electrolysis of so-called accumulator acid (sp. gr. 1.18) at room temperature with 1 ampère per sq. dcm. until hydrogen is given off. The plates are then washed for 12 hours, and the coating is oxidized to lead peroxide on half of them, by making them anodes in a similar electrolysis of a more dilute acid of sp. gr. 1.09. An uninterrupted current of 1 ampère per sq. dcm. must be passed until oxygen is freely evolved. The reduction requires about as long as the formation of the original coating, the oxidation about twice as long; the whole process requires 4 to 5 days.

Chemical Effects of Ultra-Violet Rays on Gases. D. BERTHELOT and H. GAUDECHON. (*Comptes rendus*, cl, 1327.)—Under the influence of the ultra-violet rays, cyanogen is practically completely oxidized to carbon dioxide and nitrogen. A mixture of ammonia and oxygen yields nitrogen and water, but free hydrogen is not oxidized appreciably by oxygen at the ordinary temperature under similar conditions. Formic acid is produced by the action of ultra-violet rays on mixtures of acetylene and ethylene with oxygen.

Production of Metallic Deposits. U. SCHOOP. (*Comptes rendus*, cl, 1044.)—Objects can be covered with a deposit of any fusible metal or alloy, by forcing the fluid metal through a suitable jet by the pressure of some inert gas. A coating can thus be produced upon almost any material from 0.02 mm. to several mm. in thickness. The temperature of the metallic stream just beyond the jet is between 10° and 60° C. A high pressure of 20–25 kilos per sq. cm. should be used. Tin, lead, copper and aluminum and its alloys can be deposited by this process.

Diffusion of Certain Coloring Matters. LEO VIGNON. (*Mon. Sci.*, xxiv, 821.)—The chemical type appears to have no influence on diffusion. Coloring matters, which have no diffusible power, are marked by a strong molecular condensation; they exist, in a condition of pseudo-solution, as solid granules which are extremely minute, and do not change the limpidity of the solution as apparent to the unaided eye. Coloring matters of this type are called *substantive*; they adhere indifferently upon all textiles, on account of their molecular attraction, after the manner of insoluble coloring matter. Their fixation is facilitated by the very fine division of the granules. In fact the study of diffusion shows that coloring matters form two well defined groups; those of the first group give true solutions (of the type of picric acid): those of the second group are, to speak accurately, insoluble and form pseudo-solutions (of the type of congo red).



The JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

SEPTEMBER, 1910

No. 3

THE REFLECTING POWER OF VARIOUS METALS.

BY

W. W. COBLENTZ.

INTRODUCTION.

THE present observations are the result of an attempt to obtain a more thorough knowledge of the optical properties of the metals used in incandescent lamps. Several other elements on the border line between the metals and non-metals not heretofore examined are included, since the data are of general interest.

In a paper on the radiation constants of metals¹ attention was called to the fact that all the pure metals thus far examined have the common property of a low reflecting power in the ultra-violet and in the visible spectrum which rises more or less abruptly to very high values beyond 2μ in the infra-red, and that it is therefore not unreasonable to assume that the unexamined metals, such as tungsten and osmium, have this same property. This follows from the fact that all the members of a group of chemically related substances have similar physical properties. As will be noticed on a subsequent page, this assumption of a low reflectivity in the visible spectrum has been verified to a degree far beyond expectation.

¹ Bulletin Bureau of Standards, 1908, v. p. 339. See also this Bulletin, 1907, ii, p. 470, for illustration of the reflectivities of various metals.

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

Since the reflectivity of metals is a smooth and continuous function of the wave-length in the infra-red, there is no reason for expecting these (heretofore) unexamined metals (tungsten, tantalum, etc.) to behave otherwise. Their spectral energy curves must therefore be smooth and continuous in the infra-red (no indentations or protuberances), and experimental curves showing such indentations are to be regarded with suspicion as to the accuracy of the observations.

It is difficult to show experimentally this selective emission in other than colored metals (*e.g.* gold and copper) by means of emission spectra, and since the emissivity in the short wave-lengths appears to have only a small temperature coefficient it is possible to gain some knowledge of the emissivity of the metal at high temperatures by determining its reflectivity at low temperatures. That it is permissible to apply data obtained at low temperatures to the same substance operated at high temperatures follows from the recent work of Hagen and Rubens² in which it is shown that for wave-lengths less than 4μ the optical constants of metals vary but slightly, if at all, with change in temperature, which is the region of the spectrum of interest in the question of the selective emission of incandescent lamps with metal filaments. We have therefore a positive qualitative proof of the much discussed and much overworked application of "selective emission" to explain the high luminous efficiency of the tungsten lamps. As will be noticed in the appended illustrations, the selective emission must lie in the visible spectrum. Here the emissivity is almost 50 p.c. (for tungsten) while in the infra-red it is only from 4 to 10 p.c. that of an ideal radiator, or "black body."

In the present experiments a fluorite prism, a mirror spectrometer, and a new vacuum bolometer were used. The unknown metal was compared with a new silvered glass mirror of which the reflecting power is known. The absolute value of the reflectivity of the unknown was obtained by multiplying the observed reflectivity by the reflectivity of silver given in Table II (data from Hagen and Rubens).

A Nernst glower was used as a source of radiation, which

² Hagen and Rubens, *Phys. Zeitschrift*, 1910, xi, p. 130; *Verh. Phys. Gesell.*, 1908, x, p. 710.

permitted making observations in the extreme blue and at 10μ where the fluorite prism is almost opaque. Since the glower is very narrow it is necessary to have a very accurate adjustment of its images, reflected from the two mirrors upon the spectrometer slit, so as to avoid a systematic error in the reflectivity. The observations in the infra-red were further verified by using a Nernst "heater" instead of the glower. In the blue and beyond 8μ in the infra-red the accuracy is of the order of 2 to 3 p.c., while in the intervening region the accuracy is of the order of 1 per cent. There is no difficulty in obtaining high accuracy since we are only concerned with ratios of two numbers (galvanometer readings) which are of nearly the same value, and which are subject to the same errors of observation. In view of the physical nature of the material, and especially of the size of the specimens obtainable, and also of the indirect comparison with silver, it would be illusory to attempt to attain a higher accuracy for the absolute values. This is especially true of tungsten and molybdenum in which the mirror surface was ground upon one face of a rectangular prism of the pure metal, $20 \times 6 \times 6$ mm. on an edge, kindly prepared for us by the General Electric Company. The narrowness of the specimen does not permit the grinding and polishing of an optically plane surface. The dimensions of the tantalum mirror were $15 \times 10 \times 1$ mm.; it was prepared by Siemens and Halske and was optically plane and highly polished. The close agreement between the observed reflectivity of tungsten and molybdenum at 12μ and the theoretical value obtained from a knowledge of the electrical conductivity is therefore to be regarded as somewhat accidental. The angle of incidence of the light upon the mirrors was from 12° to 15° which is sufficiently small to be considered normal incidence and hence the loss by absorption (100-Reflectivity) is a measure of the emissivity of the metal.

From his observations on the optical constants (the refractive index, n , and extinction coefficient, k ,) at 0.579μ Wartenberg³ computed the reflecting power of various metals, some of which are included in the present paper. It will be noticed in Table I that the results obtained by the two methods are in excellent agreement.

³ Wartenberg, Verh. Deutsch. Phys. Gesell., 1910, xii, p. 105.

TABLE I.

Substance	Reflecting power	Substance	Reflecting power
Manganese.....	63.5 p.c.	Tungsten.....	48.6; 51*
Chromium.....	69.7; 55*	Palladium.....	65.0
Vanadium.....	57.5; 57.5*	Rhodium.....	78.3; 77.5*
Tantalum.....	43.8; 45*	Platinum.....	72.5
Niobium.....	41.3	Iridium.....	74.6; 75*
Graphite.....	22.3; 23*	Silicon.....	35.7; 32*

* Observations by W. W. C.

It will be noticed that even in the visible spectrum the same magnitude of the reflectivity is to be found within a group of metals; for example, in the platinum group the reflectivity does not fall below 70 per cent., while in the chromium group the reflectivity centres about the 60 per cent. point. However, only beyond 12μ is this relationship true in general.

TUNGSTEN.

The area of the mirror examined was 5 mm. x 17 mm. This specimen was made from the pure material, which is somewhat brittle and did not permit a polished surface perfectly free from pores, except in the centre. This causes a slight scattering for wave-lengths up to 3μ (see discussion under graphite).

In Fig. 1 it will be noticed that the reflectivity of tungsten rises abruptly from a low value of 50 per cent. in the yellow to 89 per cent. at 2.5μ beyond which point it increases gradually to 96 per cent. at 10μ . This is a characteristic of pure metals.

Hagen and Rubens⁴ have shown that for long waves (greater than 12μ) the absorption (100-Reflectivity) of a metal may be computed from its electrical conductivity, by means of the formula,

$$100-R = \frac{36.5}{\sqrt{c\lambda}},$$

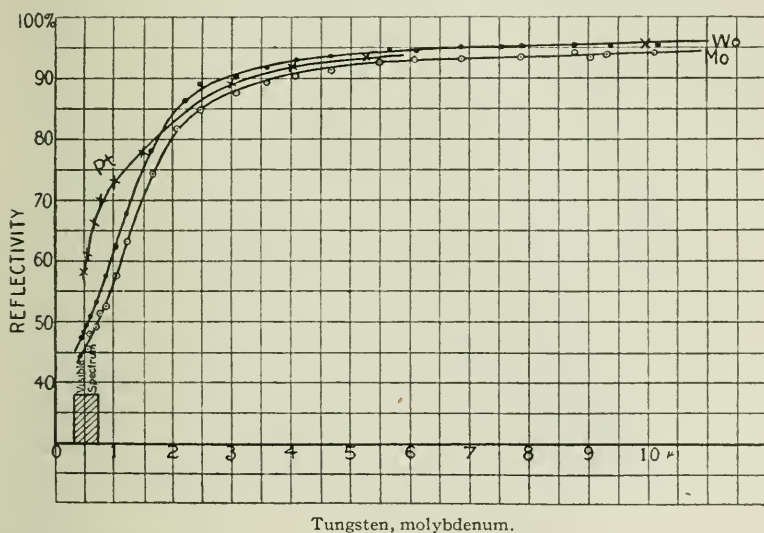
where R is the observed reflecting power, c is the reciprocal of the resistance, in ohms, of a conductor 1 mm. long and 1 sq. mm. in cross-section, and λ = wave-length in μ = 0.001 mm.

The specific resistance of a squirted rod (hence probably not so pure as the mirror material) of tungsten 20 cm. long and

⁴ Hagen and Rubens, Ann. der Phys., 1903 (4), xi, p. 873; Coblentz, Bulletin Bureau of Standards, 1907, ii, p. 470.

1.2 mm. in diameter was determined by Mr. J. H. Dellinger to be 0.000,0069 at 21.8° C. or 3.99 times that of copper. The sample of tungsten, upon which the reflectivity observations were made, had a specific resistance of 0.000,0063 at 21.5° C., or 3.66 times that of copper. Its density was 10 (true value about 19 or 20) which indicates that there were hollow spaces along the axis of prism of metal, which was about 2.5 cm. long, and had been broken from a much longer rod. At one end of this specimen there was a small cavity, but it was not possible to tell how

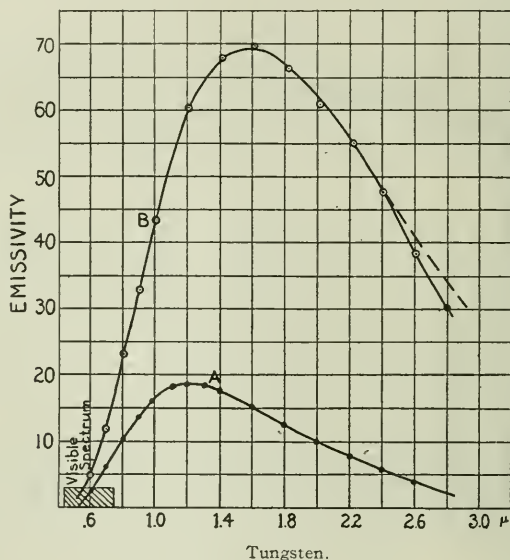
FIG. 1.



far it extended along the central axis of the specimen. This would cause a higher resistance than the true value. Recent determinations by Fink and by Parani indicate a specific resistance of about 0.000,005 for annealed tungsten. From the specific resistance of this sample of tungsten the computed reflectivity, from the aforesaid formula using $\lambda = 12\mu$ is 97.3 per cent., while the value obtained by extrapolating from 10μ is 96.3 per cent. As already stated, this is in closer agreement than is to be expected from the observations, and from the size of the mirror employed. It may be noticed in Table II that the infra-red reflectivity of tungsten is the same as that of platinum, and in the visible it is the same as that of steel. For a perfectly polished

surface, free from pores, the reflectivity of tungsten would be somewhat higher out to 2μ , because of the elimination of the diffuse reflection which obtained in the present sample. (See graphite, which gives an extreme case of diffuse reflectivity.) The results show that in the previous investigation of the radiation constants of metals, it was permissible to assume that the same emissivity function obtains as in platinum, with, of course, different numerical values of the constants.

FIG. 2.



In Fig. 2, curve *A*, is given the spectral energy curve of a new 110 volt, 32 candle-power tungsten lamp when on a normal operation of 55 watts. The mean value of the radiation constant for this lamp was previously computed (see foot-note 1) to be about $a=6.5$, the variations in the individual computations being rather large. A new spectrometer calibration has just been computed which is more accurate than the one then employed. The new computation of this radiation constant is not sufficiently different from the old one to warrant a revision of the data then published, although the individual computations are in closer agreement. The new value of the $\lambda_{max}=1.225\mu$ (old $\lambda_{max}=1.257\mu$) and the new $a=6.2$,—the shift in the new calibration

curve being about 0.02μ toward the short wave-lengths. On the basis of the new calibration curve the wave-lengths of maximum emission are too large by about 0.02μ . The radiation constants are also too large by 3 per cent. to 5 per cent. Since the individual computations vary by this amount, and since different samples of the metal filaments seem to be subject to variation, the old values are probably as trustworthy as would be the revised ones. The experimental data does not indicate a variation of the constant " a " with wave-length.

The reflection curve and the radiation constant ($a=6.2$) are in close agreement with that of platinum. We are therefore in a position to make comparisons with platinum of which the radiation constants are fairly accurately known. Using the $\lambda_{max} T=2620$ of platinum, and the observed $\lambda_{max}=1.225\mu$ of tungsten, the operating temperature of the aforesaid lamp was 1870° C.

From the observed radiation curve A , Fig. 2, we can obtain the black-body curve B , at the same temperature by dividing the observed emissivities by the observed absorptivities (100-Reflectivity) of tungsten given in Fig. 1. The maximum emission lies at about $\lambda_{max}=1.45\mu$ from which the computed temperature is about 1760° C. This value is no doubt somewhat too low, because no account was taken of the loss by diffusion in the reflection curve at 0.6 to 2μ . Using the reflectivity values of platinum which are in all probability higher than the true values of tungsten, the $\lambda_{max}=1.38\mu$ in place of $\lambda_{max}=1.45\mu$ and $t=1860^{\circ}$ C., which is probably too high. The computed values of a , from curve B , Fig. 2, vary from $a=6$ to $a=5.5$ while the experimental value for a "black body" is $a=5$. This shows that curve B is not a true "black body" radiation curve. There are two evident reasons for this discrepancy. First, the observed curve A has not been corrected for absorption by the glass walls of the lamp, which would give an emissivity at 2.5μ somewhat as shown by dotted lines in Fig. 2. Second, the reflectivity is not known with sufficient accuracy at 1.5 to 2μ (because of diffuse reflection due to the fine pores in the specimen examined) where a small error in the reflectivity has a very large effect in the position of the maximum of the radiation curve. If it were not for this difficulty, this method could be used for estimating temperatures of metal filaments of known reflecting power (using perfect mir-

rors for determining the reflectivity), but of which it is impossible to measure the temperature directly. Since the emissivity and the reflectivity are functions of the refractive index and of the absorption coefficient, and since in considering the emissivity we are not concerned with the scattering effect, it does not seem necessary to consider the question of the "blackening" of the radiation due to the porosity of the filament, so long as the size of the pores are of the same magnitude as the wave-length of the emitted light. This case seems to be different from the experiment in which the mechanical scratches, made in a strip of incandescent metal, show a higher emissivity than the outer surface. The present observations and those of Waidner and Burgess⁵ seem to indicate that on "normal" operation the tungsten filament is at a temperature of 1850° C. to 2000° C.

TABLE II.

Wave-length in μ =.001 mm.	Silver	Plati- num	Tungsten	Molyb- denum	Iron	Tanta- lum (Waten- berg's sample)	Chrom- ium	Anti- mony	Magne- sium	Graph- ite
0.40	84.0	48.0	47.0	44.0	.....	.....	.....	.....	.....	21.0
0.46	89.0	55.0	48.2	44.6	.....	.....	.....	.....	.....	22.0
0.5	90.0	58.4	49.3	45.5	55.0	38.0	55	.....	72.0	22.5
0.6	92.5	64.2	51.3	47.6	57.5	45.0	.....	53	73.0	23.5
0.7	94.2	69.0	54.0	49.8	59.5	.....	56	.....	.....	24.0
0.8	95.1	70.3	56.3	52.3	61.5	64.0	.....	.....	.....	25.0
1.0	96.4	73.0	62.3	58.2	65.0	78.0	57	55	74.0	26.8
1.2	97.2	75.0	68.2	63.6	68.5	84.0	.....	.....	.....	28.3
1.4	97.6	76.8	73.8	69.0	71.5	86.5	59	.....	75.0	30.0
1.6	97.8	78.0	78.0	74.2	74.3	88.0	61	58	.....	32.0
2.0	97.9	80.6	84.6	81.6	78.0	90.5	63	60	77.0	35.2
2.5	97.9	.....	89.2	85.5	81.5	91.6	66	.....	79.0	39.5
3.0	98.0	88.8	90.5	87.6	84.5	92.3	70	65	80.5	43.0
3.5	98.3	.....	92.0	89.2	87.5	92.8	.....	.....	.....	46.0
4.0	98.4	91.5	92.8	90.5	89.5	93.0	76	68	83.5	47.5
5.0	98.5	93.5	94.0	92.0	91.5	93.0	81	.....	86.0	50.5
6.0	98.6	.....	94.6	93.0	93.0	.....	85	70	88.0	52.0
7.0	98.6	95.5	95.1	93.3	94.0	93.5	.....	.....	91.0	53.5
8.0	98.8	95.1	95.6	93.7	94.0	93.8	89	.....	93.0	55.5
9.0	98.9	95.4	95.5	94.0	93.8	.....	92	72	93.0	57.5
10.0	99.0	95.9	95.5	94.5	.....	.....	93	.....	.....	59.0
12.0	98.9	96.5	96.3	95.2	.....	95.0	97	.....	.....	.....
12	.....	.....	97.2*	97.3*	.....	95.7*	.....	.....	.....	.....

* Values computed from the electrical conductivity.

MOLYBDENUM.

The area of the mirror examined was 5 mm. x 17 mm. The reflecting surface had a very much higher polish than the sample of tungsten just described. To the eye it was apparent that the

⁵ Waidner and Burgess, Bulletin Bureau of Standards, ii, p. 319.

molybdenum had a higher absorption than the tungsten mirror. This is illustrated in the bolometric comparison shown in Fig. 1 which indicates a reflectivity of only 46 per cent. in the yellow, which rises abruptly to 85 per cent. at 2.5μ beyond which point the reflectivity gradually increases to 95 per cent. at 10μ . The specific resistance of two samples of molybdenum wire, drawn to a uniform diameter, was determined by Mr. Dellinger. The wires were respectively 15 cm. and 20 cm. in length, 0.627 mm. and 0.815 mm. in diameter, and the corresponding specific resistance was 0.000,0064 and 0.000,0062 at 21.5° . This is about 3.6 times the resistance of copper and practically the same as that of tungsten. From this it appears that the reflectivity of molybdenum should be as high as that of tungsten at 12μ . The observations indicate the opposite condition. No systematic errors could be detected in the observations and the only explanation which can be offered at present is that the size of the reflecting surfaces was too small to establish a true absorption to a greater accuracy than 2 per cent. at 12μ . This, however, is not a large discrepancy when it is recalled that in some of the earlier work, using larger mirrors of known curvature, errors almost as large as these are on record.

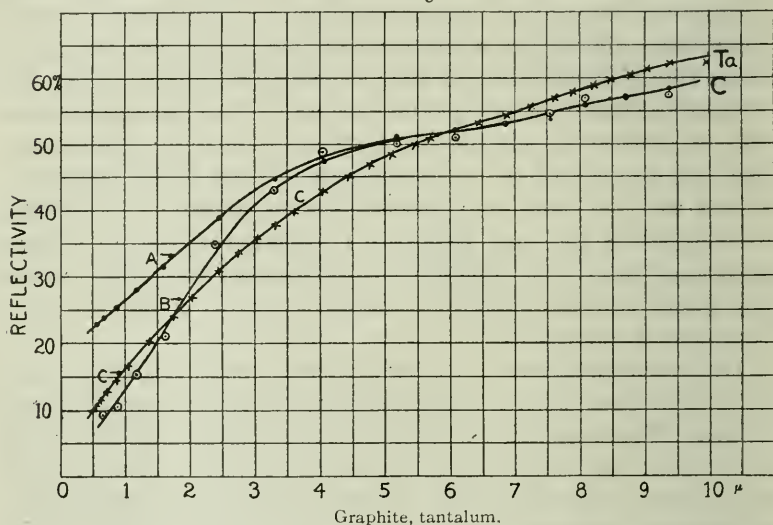
The reflectivity curves of molybdenum and tungsten are so nearly alike that from a consideration of their emissivities and luminous efficiencies there seems to be no great choice in the use of these two metals in incandescent lamps. On the other hand, from a consideration of their physical properties, the molybdenum filament would be the preferable because of its toughness and its ductility, in contrast with tungsten which is very brittle. Their melting points are high, and it is principally a question of overcoming certain physical weaknesses in the molybdenum in order to make it practical.

GRAPHITE.

Two samples of graphite were examined, the one being the natural mineral from Siberia. Its reflecting surface was 4 cm. \times 5 cm. The second sample, curve *B*, Fig. 3, was a longitudinal section of a rod, 8 mm. in diameter, of Acheson's graphite. It could not be burnished free from pores which were rather large, and which caused a scattering of the radiation, out to 4μ in the infra-red. Beyond this point it reflects as highly as the natural

Siberian mineral, shown in curve *A*, Fig. 3. The natural mineral was very compact, but showed the rays and fibrous structure of the original plant or tree from which it was formed. It was burnished or "polished" on a semi-matte piece of plate glass. A thoroughly ground glass was too rough, while the smooth plate was found equally inapplicable. The partly ground glass seemed to hold just sufficient material to work into the softer parts without accumulating sufficient loose material which would roughen the surface. The glass plate was kept wet with

FIG. 3.



clean water and by the application of some pressure it was possible to prepare a very highly polished surface.

The reflectivity is 23 per cent. in the yellow, gradually increasing to 63 per cent. at 10μ . From this low reflectivity at 2μ in the infra-red there results a high emissivity, hence the graphitized carbon filament cannot have the same luminous efficiency as the tungsten lamp at the same temperature, although it has the higher emissivity in the visible spectrum.

TANTALUM.

The utilized area of the tantalum mirror was 9 mm. x 14 mm. In spite of its excellent polish, it showed an exceedingly low reflectivity throughout the spectrum, as compared with pure metals.

The curve *C*, in Fig. 3, represents three series of observations, using different adjustments, the measurements usually agreeing to one part in 100 to 200. In the visible spectrum the reflectivity is only 10 per cent. which gradually increases to 63 per cent. at 10μ . There is no indication of an approach to constant reflectivity, in the infra-red, such as obtains in pure metals. Subsequent correspondence with the maker showed that this surmise of an impure metal was correct. The surface was rendered impure by working and polishing which, by the action of gases, formed an exceedingly hard surface layer. From the writer's experience it appears that the ease with which a tantalum mirror becomes contaminated in polishing depends upon the previous history of the metal. For example, the regulus of tantalum obtained from Von Wartenberg⁶ had never been rolled or hammered and it was found that, in polishing it, any contamination, such as for example the blackening caused by a film of oil, was easily removed. On the other hand, a film of oil on the mirror just described, which had evidently been worked down from a regulus (Fig. 3, *C*) formed a brown coating which was removed with great difficulty.⁷ The rear side of this mirror was therefore ground flat on fine emery paper, which for the final polish was rubbed over with a layer of alcohol and graphite. By stroking lightly and lifting the mirror soon after the alcohol had entirely evaporated, a clean surface was produced which was almost free from scratches. The old surface, of which the reflectivity is given in Fig. 3, was so hard that it could not be polished by this method.

The contrast between the reflectivity of the old contaminated surface, and of the new surface, polished as just described, is shown in Fig. 4. Curve *C* gives the reflectivity of the new surface as produced by the fine dry emery paper, the scratches being quite deep. Curve *A* gives the reflectivity of the same mirror after giving it the final polish with graphite and alcohol when only very fine scratches remained. In the latter case the scattering is almost eliminated, and the reflectivity rises abruptly

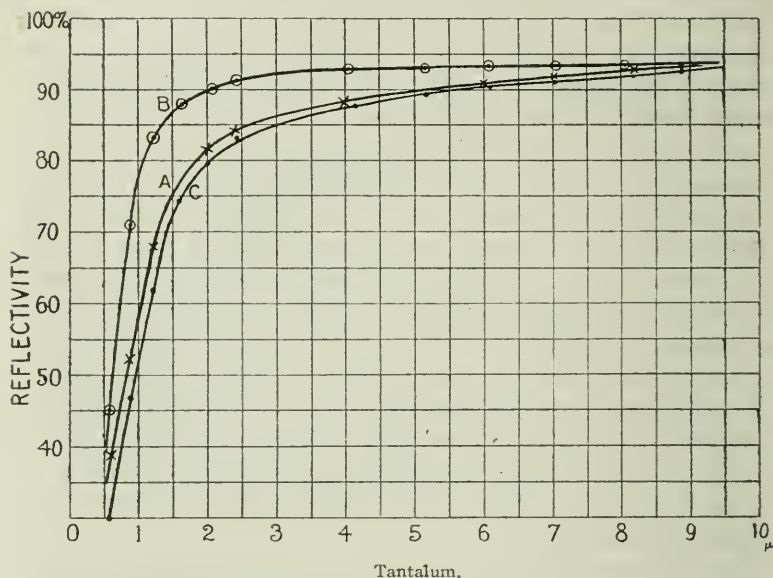
⁶ Von Wartenberg, Verh. Phys. Gesell., 1910, xii, p. 121. He found that tantalum was not contaminated by polishing.

⁷ See also a recent investigation by Parani, Vehr. Phys. Gesell., 1910, xii, p. 301, who likewise finds that tantalum is easily contaminated by gases.

from 39 per cent. in the yellow to 85 per cent. at 2.5μ beyond which point the rise is gradual to 94 per cent. at 9μ . The theoretical reflecting power, at 12μ , computed from the electrical conductivity is about 95.7 per cent.

Through the kindness of Dr. Von Wartenberg an opportunity was granted to examine the tantalum regulus mirror used by him in determining the optical constants in the visible spectrum. The area of surface which could be used was only about $2.5\text{ mm.} \times 3$

FIG. 4.



mm. and hence it was impossible to obtain the absolute reflectivities with high accuracy. There was no difficulty in obtaining the relative values for different parts of the spectrum, which is the point of most interest. The surface of the mirror was perfectly free from scratches. The reflectivity, which is shown in curve B, Fig. 4, rises even more abruptly to high values than was found in the first sample. In this respect, pure tantalum, zinc, and silver stand unique among the metals. Because of the steepness of the reflectivity curve, the emissivity of tantalum in the visible spectrum must be more selective than obtains in tungsten and molybdenum. Furthermore, since the reflectivity of *pure*

tantalum is higher than that of tungsten at 1 to 2μ it must have the higher luminous efficiency.

The reflectivity of the regulus of pure tantalum as observed by the two methods (Wartenberg computed R from the "optical constants") is about 45 per cent. in the yellow. The other mirror appeared much darker, so that the lower reflectivities as shown in Fig. 4 are to be attributed to impurities. The tantalum regulus appeared as bright as the prism of tungsten already described. The most casual observation shows that the tungsten filament has a much whiter metallic luster than a tantalum filament. This may be due to contamination in drawing the tantalum wire, especially if drawn with oil as a lubricant. It appears that in tungsten all the impurities can be driven off at high temperatures. This is not necessarily true of tantalum, which occupies an anomalous position in the scale of luminous efficiencies of metals.

From the observations of Waidner and Burgess, who found that the "normal" operating temperature of tantalum is about 2000° C., it is evident that its low luminous efficiency is not due to a low operating temperature, such as would be necessary with platinum.

Incandescent lamps of tungsten and osmium have an efficiency of about 1.25 watts per candle while for no apparent reason tantalum must be classified with graphitized carbon with an efficiency of about 2 to 2.5 watts per candle.

The foregoing data on the reflectivity of tantalum and graphite, Fig. 3, shows that this classification is consistent. The radiation constants of these two substances are almost the same (total radiation; tantalum proportional to the 5.3-power of temp.; graphitized filament proportional to the 5.1-power of temp.) and the manner in which they differ is in the right direction, since graphite is a non-metal. Hence, while it was somewhat contrary to expectation to find such a low reflectivity in the infra-red for impure tantalum this is not inconsistent with other data such as the radiation constants.

There seems to be a prevailing notion that the polish of the metal filament is of great importance, but it is not apparent how roughness or scratches can cause a "blackening" of the radiation by successive reflection within the cavities so long as the latter are of the order of the wave-length emitted. It is the

absorption coefficient and the refractive index that must be considered. This is especially conspicuous in tantalum filaments. When new they have a "brownish" lustre, while the filaments of old lamps are decidedly black. Similar filaments of osmium retain their gray appearance even after becoming crystalline. Under the microscope the crystalline tantalum filament appears much darker than tungsten, although the actual polish of the crystal surfaces of the latter is much higher. Some crystals appear as dark as highly polished jet or fine grains of stibnite which has a reflectivity of only about 35 per cent. This low reflectivity in the visible spectrum produces a high emissivity, but, contrary to the properties of the pure material, the reflectivity continues low (emissivity high) in the infra-red, which tends to lower the luminous efficiency.

The ideal solid illuminant must fulfil the conditions of a high operating temperature and a high emissivity in the visible spectrum. As shown in Fig. 1, of all the metals thus far examined, tungsten approaches nearest to the fulfilment of these conditions.

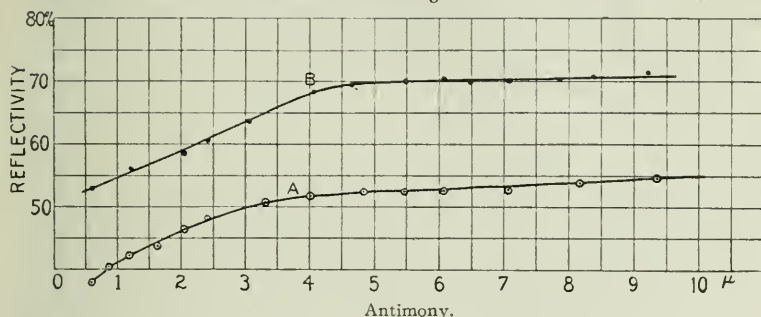
ANTIMONY.

It was found impossible to produce a perfect mirror of antimony, so that the absolute values obtained have little weight. Since the main object in the present work is to show the relative values of reflectivities in the visible as compared with the infra-red, the results obtained on several antimony mirrors are here recorded. As with all the other metals, larger surfaces, either plane or of known curvature, must be used for high accuracy in the absolute values.

Two samples of antimony were examined, the one being a mirror (5 mm. x 17 mm.) polished upon a cleavage plane of a large crystal of the metal, the other being a mirror formed in vacuo by cathode disintegration. The reflectivity of the polished cleavage piece is shown in curve *A* of Fig. 5. The reflectivity is low, due to the presence of numerous large-sized pores which resulted in the polishing. Two cathode mirrors were also examined. The first one contained small holes caused by dust particles on the glass surface which seemed to permit radiation from the rear surface of the glass (2 mm. in thickness) to return on its path, thus causing a wavy reflection-curve with maxima of about 65 per cent. at 1.2μ , 2.5μ , and 4μ , and minima of 55 to 60 per

cent. at 2μ , 3.3μ , and 6μ beyond which point the reflectivity increased gradually to 68 per cent. at 9μ . On removing the rear mirror surface these maxima and minima were destroyed. A second mirror (5 mm. \times 17 mm.), free from dust holes, and with the rear surface of glass free from metal, was examined, the data being plotted in curve *B* Fig. 5. The reflectivity rises from 53 per cent. in the yellow to a fairly uniform value of 72 per cent. at 9μ . In view of the difficulty in producing a mirror, which is free from carbon, by the cathode discharge, and in view of the fact that the mirror seemed darker than one would expect, judging from the appearance of the crystals, it seems probable that the reflectivity is somewhat higher than here recorded. However, in view of the fact that antimony departs considerably from the true metals, the low reflectivity throughout the spectrum is prob-

FIG. 5.



ably to be expected, as will be noticed presently in several other metals which lie on the borderline between the electrical conductors and the insulators.

In conclusion, it may be added that cathode mirrors of antimony are easily produced in 5 to 7 minutes, by using a heavy current. The tendency is for one to continue the discharge for a longer period than this, with the resultant oxidation of the central part of the mirror. By using a residual atmosphere of hydrogen and a low current, excellent large-sized mirrors are produced in half an hour.

RHODIUM.

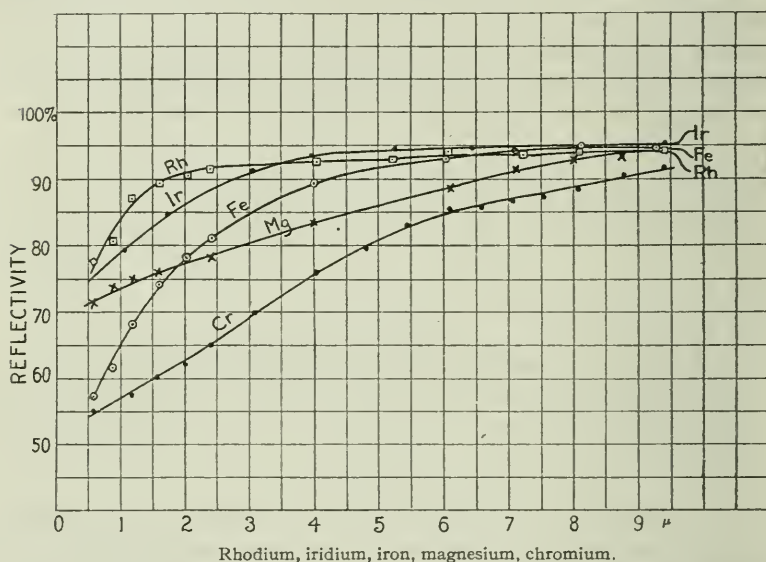
The sample examined was kindly loaned by Dr. Von Wartenberg. The area of the surface examined was 5 mm. \times 5 mm. Several small blow-holes were present, which, with the smallness of the surface, did not permit high accuracy in the absolute values

of the reflectivities. The reflecting power, Fig. 6, rises abruptly from 77 per cent. in the yellow to 92 per cent. at 2.5μ beyond which point the rise is gradual to about 94 per cent. at 9μ .

IRIDIUM.

The mirror examined was a thick plate of the metal, which in the polishing had not been perfectly freed from pores which caused scattering. The reflectivity in the yellow was only 53 per cent., which increased to 75 per cent. at 2μ and to 90 per cent.

FIG 6



at 8μ . This same plate was examined several years ago⁸ when it had a finer polish. The reflectivity, Fig. 6, was found to increase from 79μ per cent. at 1μ to 95 per cent. at 99μ . Its reflectivity seems to be somewhat higher than platinum in the visible spectrum.

IRON.

The sample of iron examined is probably the purest obtainable. Its purity was 99.8 per cent. The chief impurities were 0.15 per cent. copper, 0.02 per cent. manganese, and 0.02 per cent. carbon. The sample took a high polish and reminded one

⁸ Bulletin Bureau of Standards, 1907, ii, p. 470.

somewhat of palladium in its general appearances. The reflectivity, Fig. 6, rises gradually with increase in wave-length and, throughout the spectrum, the values are about 2 per cent. higher than the values previously observed on steel by Hagen and Rubens.

MAGNESIUM.

The mirror examined had a surface of about 1.2 cm. x 2.5 cm. It was polished with considerable difficulty. A highly polished surface free from scratches was finally obtained by wet-grinding on fine emery paper, using tin oxide ("putty powder") and then (dry) polishing the surface on chamois skin with a little putty powder. This procedure prevented the formation of a film of oxide. However, the surface was not entirely free from blisters, so that the reflectivities are somewhat higher than recorded in Fig. 6. The reflectivity curve is somewhat different from that of a pure metal, especially of aluminum (see *Bulletin Bureau of Standards*, ii, p. 470). The alloy of aluminum and magnesium, magnalium, has a reflectivity curve which falls between these two metals.

CHROMIUM.

The sample of chromium was sawed from a lump of the metal made by the Goldschmidt process. The material was quite crystalline, but took a fairly high polish, excepting the usual pores which were rather large as compared with tungsten. The reflection curve, Fig. 6, increases gradually from 55 per cent. in the yellow to 91 per cent. at 9μ . Judging from previous experience with other metals it seems quite certain that, for a perfect mirror surface of non-crystalline material, the reflectivity of chromium would be higher in the yellow, as observed by Wartenberg. While part of the low reflectivity of chromium is no doubt due to diffuse reflection, out to 5μ , it is to be noted that this metal produces acid compounds, just as was observed with antimony, and in its general properties cannot be classed with the true metals. Hence its unusual reflection spectrum is to be expected.

VANADIUM.

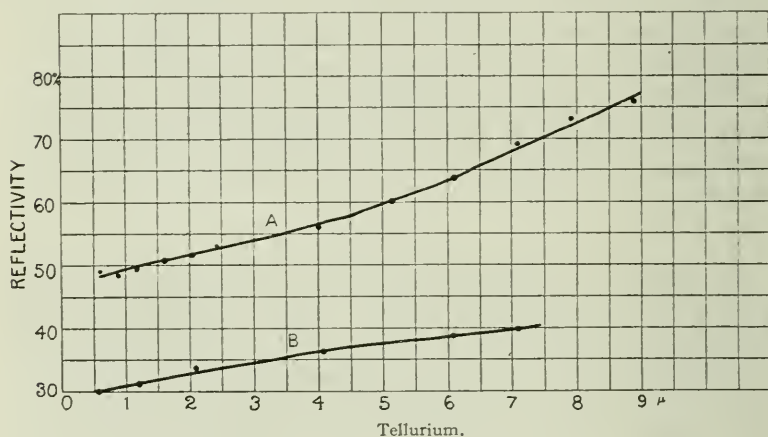
The sample examined was kindly loaned by Dr. Von Wartenberg. The surface was plane, highly polished, and the area examined was about 5 mm. x 5 mm.

The reflecting power, curve *C*, Fig. 8, rises gradually from 58 per cent. in the yellow to 92 per cent. at 9μ . In this respect it is very similar to chromium and iron, Fig. 6. This is to be expected since they fall in the same group in the Mendeleeff series.

TELLURIUM.

A knowledge of the reflectivity of tellurium is of interest because it occurs on the borderline between metals and non-metals and has a high electrical resistance. It is usually found in a highly crystalline state and is therefore difficult to polish a

FIG. 7.



surface free from pores. The reflectivity curve of such a mirror is given in curve *B*, Fig. 7. It is of interest only in showing the general trend of the reflectivities in various parts of the spectrum. The absolute values would be much higher if a correction could have been made for the loss by scattering caused by the roughness of the surface.

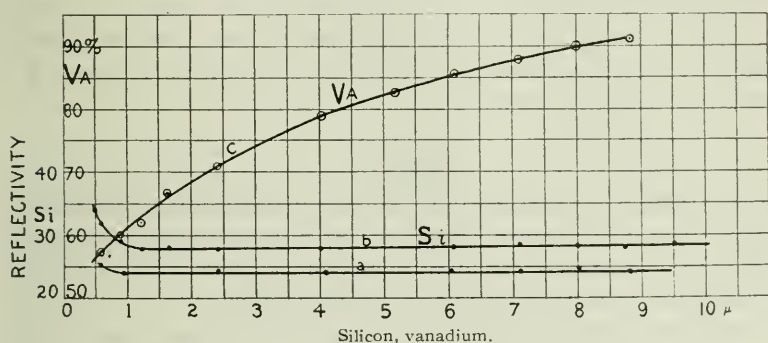
The best mirror used in the present examination was produced by the cathode discharge in hydrogen. It was found that unusually large-sized mirrors can be deposited in this manner, the time required being about half an hour. Thin deposits of tellurium transmit a reddish-brown light, which would indicate a low reflection beyond the red or a minimum reflection in the red. This is illustrated in curve *A*, Fig. 7, where at 0.8μ the

reflectivity, after repeated observations was found to be slightly less than in the yellow. While this might be due to the lack of knowledge of the true value of the reflectivity in the visible spectrum of the silver comparison mirror, the color of the transmitted light seems to indicate such a minimum.

The occurrence of a reflectivity minimum so far in the red is unusual in the true metals. However, the characteristics of tellurium are so different from the usual ones of true metals, that such an unusual reflecting power is probably to be expected.

The construction of a thermopile having large surfaces usually results in a sluggish instrument because of its great heat capacity. It has been suggested to deposit by cathode discharge

FIG. 8.



two metals (for example, Te-Cu) upon some material which can afterwards be removed. These two films of metal are to overlap along one edge, which forms the active junction. The thermo-electric power of tellurium is very high, and in view of the ease with which a film of this metal can be deposited, it might prove satisfactory as a surface thermopile.

SILICON.

A knowledge of the reflectivity of this element is of interest because it belongs to the non-metals or insulators. Two samples were examined. The polishing was done on a fine grade of emery paper covered with a layer of tin oxide and a little graphite. The one sample, from Kahlbaum, curve *b*, Fig. 8, was quite homogeneous and took a very high polish, free from scratches. The second sample from The Carborundum Company, curve *a*,

Fig. 8, was less homogeneous, its hardness was greater and it took a poor polish. The crystals, as they come from the furnace, are of a bluish color, as was also true of the highly polished remelted sample here examined. This causes a high reflectivity in the visible (blue) spectrum, which decreases rapidly to a uniform value of 28 per cent. beyond 1μ in the infra-red. The lower value of 24 per cent. in curve *a* is due to the porosity and to the consequent diffuse reflection by this sample of silicon. From an examination of these two samples it appears highly improbable that the absolute values of the reflectivities, to 10μ in the infra-red, are much greater than 30 per cent. It was noticed in Fig. 3 that the reflectivity of graphite continues to rise gradually with increase in wave-length. The carbide of these two elements, carborundum SiC , as well as the oxide SiO_2 , have the most remarkable⁹ reflection spectra yet observed, with bands of selective reflection which are as high in value as the reflectivity of pure metals.

SUMMARY.

The reflecting power of several new metals has been examined, including tungsten, tantalum, and molybdenum. By comparing these metals with silver, of which the reflectivity is known, the absolute reflectivities have been determined.

It is shown that in common with all the other pure metals previously examined, the present series have a low reflectivity in the visible spectrum which increases rapidly to high values in the infra-red. The reflectivity curves of tungsten and of molybdenum are so nearly alike that from a consideration of their optical properties there is no great choice in the use of these two metals in incandescent lamps. Since molybdenum is tough and tungsten is brittle, it remains to be seen whether other physical difficulties can be overcome in the former metal, to enable its introduction as an illuminant.

The reflectivity curves show that the high efficiencies of the metal-filament lamps is due to their low reflectivity (true absorption and not diffuse reflection is meant) in the visible spectrum and to a high reflectivity in the infra-red.

In tungsten this results in an emissivity of almost 50 per cent.

⁹ Bulletin Bureau of Standards, 1907. ii, p. 476.

in the visible spectrum, while in the infra-red the emissivity is less than 10 per cent. of an ideal radiator.

The ideal solid illuminant giving a high luminous efficiency must fulfil the condition of a high operating temperature, a high reflectivity (hence low emissivity) in the infra-red, and a low reflectivity (high emissivity,) in the visible spectrum. The pure metals, tungsten and molybdenum fulfil these conditions more exactly than any other known metals, excepting tantalum which as a lamp filament, however, does not have the optical properties of the samples described in this paper.

Thus far it has been impossible to obtain a large-sized sample of pure osmium, to determine its reflectivity.

In conclusion, the writer expresses his appreciation of the courtesy of Dr. Von Wartenberg in submitting his samples of tantalum, rhodium, and vanadium for examination.

NOTE I—COMMENTS ON RADIATION LAWS OF METALS.

In a previous paper¹⁰ the principal spectral radiation constant, " a ", of various metals was described. This "constant" was found to vary with the temperature and theoretical reasons were given to account for this variation. If the equation representing total radiation had been considered, $S = \sigma T^{a-1}$, then we would have had to consider the constant, " a ", as well as the constant, " σ ". The constant $C_2 = \sigma \lambda_{max} T$ also involves the temperature, as well as other factors, so that " a " was the only constant that could be investigated, as described in the aforesaid paper. Assuming a value of $a = 6$, the radiation from platinum observed by Lummer and Kurlbaum,¹¹ shows a variation in the constant of total radiation from $\sigma = 8.24$ to $\sigma = 11.16$ for an increase in temperature of about 1275° . It seems apparent that " σ " cannot be considered constant, for it indicates the emissivity per unit area of a surface radiating under specific conditions. Now if those conditions vary, as is true of the metals in which the absorptivity (at any wave-length) is a function of the temperature, it would seem that the " a " cannot remain constant, but must increase with rise in temperature.

¹⁰ Coblenz, Bulletin Bureau of Standards, 1909, v, p. 339. See p. 367 for a discussion of the radiation from platinum.

¹¹ Lummer and Kurlbaum, Verh. Phys. Ges., Berlin, 1898, xvii, p. 106.

The constant, a , in the Wien equation $E = c_1 \lambda^{-a} e^{-\frac{c_2}{\lambda T}}$ and as tentatively assumed in the aforesaid computations, relates to a specific region of the spectrum; and irrespective of the writer's published data, experiments by others show that the emissivity of metals at any wave-length in the infra-red is affected by the temperature, *i.e.*, it has a temperature coefficient. But this is not all. At low temperatures the maximum emission, E_{max} , falls in the region of 3 to 6μ where the reflecting power at a given temperature is practically constant and we have to consider only the change in the radiation constant, a , due to the temperature coefficient of the reflectivity. At high temperatures the E_{max} falls in the region of 1.5μ (see Fig. 1) where at any given temperature the reflectivity changes rapidly with wave-lengths; and as it shifts toward the short wave-lengths the E_{max} must increase by a different law (from the Wien equation $E_{max} = BT^a$) from what it did when at 3 to 6μ . In the region of 1.5μ the temperature coefficient is small but the absorption (100-Reflectivity) varies rapidly with wave-length, while beyond 3μ the conditions are exactly the reverse. In both cases the emissivity, E_{max} , increases in a different manner than postulated by the simple radiation formulæ.

Now, from the Wien equation, $E = c_1 \lambda^{-a} e^{-\frac{c_2}{\lambda T}}$, the radiation constant a is computed from the equation

$$a = \frac{\log E - \log E_{max}}{\log e - \frac{\lambda}{\lambda_{max}} \log e + \log \frac{\lambda}{\lambda_{max}}} \quad (\text{Eq. 1})$$

where E and E_{max} are the emissivities at the wave-lengths λ and λ_{max} respectively. It will be noticed that the temperature of the filament does not enter into this equation. From the most recent work of Hagen and Rubens (*Phys. Zeit.*, 1910, ii, p. 139) it appears that, in the region extending from the visible to 3μ , the temperature coefficient of emissivity is extremely small and the observed variations in a with temperature, as computed from the above equation, must be due to some other cause than a true temperature coefficient of emissivity. This cause is not difficult to find if we return to the reflectivity curves Fig. 1. At low temperatures, when λ_{max} falls in the region of 2μ , the E_{max} is but slightly affected by the temperature coefficient of emissivity, and since the reflecting power varies but slowly with the wave-

length, the E_{max} will be closely that required by the Wien equation ($E_{max} = B T^a$). At high temperatures when the λ_{max} falls in the region of 1.2μ , the E_{max} falls in the region where the reflectivity changes rapidly with wave-length, and consequently the value of E_{max} must increase at a higher rate than required by the equation $E_{max} = B T^a$. The difference between $\log E - \log E_{max}$ (Eq. 1) must therefore be less than would otherwise be the case, due to this fact, and the decrease in a with temperature when computed from the above equation must necessarily follow, as observed.

From the reflectivity curves this seems a plausible explanation. Hence, an accurate value of a cannot be computed from the Wien equation as expressed in (Eq. 1). However, from the close agreement between the values of a of platinum by this and by more direct methods, it is evident that the errors resulting from the use of Equation 1 are not serious. The aforesaid work has shown in a fairly quantitative way that the constant a of tungsten is much higher than that of platinum and of carbon. The great suppression of the radiation of tungsten as compared with carbon in the infra-red is another proof of this. The Wien spectral energy curves, using different values of a , illustrate this same behavior, as may be easily verified by plotting the data given in Table I, *Bulletin Bureau of Standards*, vol. v, p. 347.

It seems evident that any spectral radiation formula which can be set up, must contain factors which will take into consideration not only the variation in emissivity with temperature, but also the variation in the absorptivity, which is a function of the wave-length and the temperature. Whether the constant a really varies¹² as found in my previous paper where the Wien equation was tentatively assumed, or whether the constant σ varies, or whether both vary, is not the all important question at this stage of our knowledge. The most important thing for the present is to get further experimental data, using wide strips of such metals, as platinum and tungsten, with a thermocouple to measure the temperatures. In this manner it is hoped to contribute more accurate data in the near future.

¹² As this paper goes to press, a short account of an investigation by Hyde, *Elect. World*, June 23, 1910, lv, p. 1654, has appeared in which the observed constancy of the ratios of the candlepowers of tungsten against carbon seems to show no temperature coefficient of emission, while for osmium

the ratios are not quite constant, indicating a probable temperature coefficient, which is in accordance with the results of other observers.

The danger of a too free indulgence in mathematical deductions, in which the physical facts are overlooked, is indicated by the derivation of two values of " σ " depending upon the radiation formula (Wien or Planck) employed. Experimentally there can be but one value of " σ " which is $\sigma = 5.3 \times 10^{-12}$ Watt per cm. The suggestion is made that the constant, C_2 , might be considered variable, which is reasoning in a circle for $C_2 = a\lambda_{max}T$, experimentally, and since C_2 did not enter into the equations used by the writer, that constant was not discussed. Of course, C_2 varies if the above equation is true.

For metals, the physical facts are:

1. An extraordinary variation in their reflectivity, from the visible to about 2μ , beyond which point the reflectivity increases but slowly with wavelength.

2. A small temperature coefficient of emissivity from the visible to 3μ beyond which point the temperature coefficient increases rapidly with wavelength.

3. For the black body the position of maximum emission in the spectral energy curve shifts, with rise in temperature, toward the short wave-lengths by a fixed amount, because only the temperature enters the problem and $\lambda_{max}T = \text{constant}$. Furthermore, the height of the maximum emission increases by a fixed amount $E_{max} = BT_a$. The total radiation progresses as $S = \sigma T_a$. The constants " a " and " C_2 " are concerned in the slope of the spectral energy curve, while " σ " defines the total emissivity per unit area of the radiator. In the pure metals the variation in E_{max} and λ_{max} will be affected (by variable amounts) by (1) and (2), and as already mentioned in the text, these formulæ, just mentioned, must be modified to take account of these facts.

It does not appear that we are contributing anything new to what was found in Germany 10 to 15 years ago when it was concluded that the Wien equation does not apply to the black body, in which the composition of the energy emitted is independent of the material forming the radiating enclosure; and if these spectral radiation formulæ do not apply to such a radiator, how can we expect them to apply (except perhaps at some one temperature, which does not appear very probable) to substances affected by the conditions (1) and (2) mentioned in the preceding paragraph.

In the paper just quoted doubt is expressed as to the accuracy of the emissivity ratios, for the region well within the visible spectrum, of carbon and tungsten lamps, operated on a color match (Bulletin Bureau of Standards, vi, p. 314, et seq.). Now, all depends upon what is meant by "well within the visible spectrum." Accurate spectrophotometric comparisons can be made to 0.68μ or 0.69μ . Abruptly at and beyond 0.7μ the photometric comparisons become more or less guess work; and yet the eye perceives this light. It may be noticed from the published curves that for a "color match" the ratios of intensities at a 0.7μ differ from those at 0.5μ by 1 to 2 per cent., which

would not be very convincing if we had no further data beyond this point. However, at 0.75μ the ratios differ by 5 to 6 p.c. from the values at 0.5μ and beyond this point the departure from the values at 0.5μ become larger with increase in wave-length, and the conclusion as to conditions at 0.7μ can be arrived at by extrapolating the incline line backward from 0.8μ . To admit that the line is rigidly horizontal throughout the visible spectrum to 0.75μ (to be inferred from the expressed doubt in the aforesaid paper), beyond which point it suddenly bends upwards, is to admit that there is a selective emission not very unlike that which obtains in the visible spectrum of incandescent gold and copper. The reflectivity curves of carbon and tungsten given herewith, show no indentations in the region of 0.7μ to 0.9μ , which would have to obtain, just as in gold and copper in the yellow, in order to give an increased emission in this region of the spectrum. The change in curvature in the graphs of Fig. 11, as shown in Bulletin Bureau of Standards, vi, p. 316, at 1.5μ to 2μ is probably to be expected, since the reflectivity of tungsten changes rapidly in this region of the spectrum, while the reflectivity of graphite increases gradually throughout this region.

WASHINGTON, D. C., May 28, 1910.

History of Portland Cement. (*Bull. Soc. d'Encour.*, cxiii, 3.)
—The *Thon-Industrie Zeitung* gives a very interesting biography of Mr. J. C. Johnson, whom it terms the inventor of cement. He was born in London in 1811. Since 1836 he was manager of White's factory. In 1824 Joseph Aspdin, a mason of Leeds, patented a process for mixing an artificial hydraulic cement, which he called Portland cement, because it resembled the calcareous Portland stone; this product was used in 1828 for Brunel's Thames tunnel. A French patent, taken by Saint Léger in 1818, is almost identical with Aspdin's, except that the material was not subjected to so high a temperature and only produced an hydraulic lime. Johnson caused Aspdin's products to be analyzed and discovered, after numerous experiments, that the hydraulic properties of the cement were due to the chalk and to a clay very rich in silica. He finally arrived at the formula, 5 of dry chalk, 2 of damp clay, a composition similar to Pasley's, but Johnson heated to vitrification. In 1848 Johnson established a factory at Rochester, and his former chief bought all his production. Then he built factories at Cliff and at Gateshead, and ended by forming the company, J. C. Johnson & Co., with Aspdin as a partner. In 1854 he invented his intermittent vertical furnace, and in 1873 he built his third factory at Greenwhithe. When 43 years of age, Johnson learned French and German for his business needs. At 87 years of age he undertook to ride a bicycle, which he never abandoned.

PHYSICAL QUANTITIES CLASSIFIED IN THE ORDER OF THEIR DIMENSIONAL FORMULAS.

BY

CARL HERING.

HERETOFORE the dimensional formulas of physical quantities have been classified according to subjects; in such tables it becomes difficult to find the physical quantity when the dimensional formula is given, and still more so to find all those which have the same or nearly the same dimensions or are closely related. In the following tables all the physical quantities have therefore been arranged in the order of their dimensions, all those of the same dimensions being brought together, and those of nearly the same being close neighbors.

Numerous other matters of interest are also brought out by such a classification, which may sometimes be of use to those dealing with dimensional formulas, the relations of quantities, the search for new quantities, the search for new fundamental systems, etc.

The dimensional formulas are here arranged in groups. All the quantities containing the factor *length* (L) form the first group. In this group they are arranged in the order of the exponent of L , beginning with the smallest, that is, in the order $L^{-3}, L^{-\frac{5}{2}}, L^{-2}, L^{-\frac{3}{2}}, L^{-1}, L^{-\frac{1}{2}}$ ($L^0 = 1$ hence absent in this group), $L^{\frac{1}{2}}, L, L^{\frac{3}{2}}, L^2, L^{\frac{5}{2}}, L^3$. The letters are given preference in the following order, $L, M, T, \mu, \kappa, \theta, \alpha$. In the second group they are similarly arranged in the order of the exponent of M , in the third in the order of that of T , and so on in each group, preference being always given to the other letters in the order just stated. Each quantity has been repeated in every group to which it belongs, thus making each one of the groups complete in itself.

The so-called "suppressed factors" μ and κ (whose dimensions are unknown) have been included, and together with θ for temperature and α for the plane angle, have been treated here

as auxiliary fundamental quantities. The dimension of an angle in this system is unity because $L \div L = 1$; this is a defect of this system and leads to such absurdities as torque=energy: the factor a has therefore been introduced here as a suppressed quantity in order to call attention to its presence.

The list of quantities was taken from the author's "Conversion Tables," p. 18-24, where they are classified, as usual, according to subjects and where their derivational formulas, symbols, etc. are also given; the latter are therefor not repeated here, as the present table is intended to supplement the usual ones.

Owing to the lack of knowledge concerning the dimensions of temperature, all the thermal quantities have here been based on four different fundamental conceptions. The first is based on the dynamical units, that is, on the formula of energy combined with a fourth fundamental unit representing temperature. The second is based on the thermal units; quantity of heat then is $mass \times temperature$; in this system the specific heat of water is unity by definition and is therefore suppressed in the formula. In the third system volume is substituted for mass in the second. In the fourth system the author has suggested eliminating θ by defining temperature to be energy per unit of mass, that is, specific mass energy; the dimensions of temperature then are those of the square of a velocity. By substituting these dimensions of temperature for θ in the dynamical and the thermal systems (the first and the second) they all three give the same results for all the thermal quantities; this is not true of the thermometric system (the third one). This is an indication that the first, second and fourth systems are rational and the third is not; also that temperature is probably the square of a velocity; there are also other reasons for this same conclusion.

In general, whenever the dimensional formula is not definite, several of the probable ones are given, which accounts for the same quantity sometimes appearing with different formulas. The formulas for some of the less usual quantities were taken from the Smithsonian Physical Tables.

The abbreviations "elmg" and "elst" mean the electro-magnetic and the electrostatic systems respectively.

CLASSIFIED ACCORDING TO LENGTH (L).

$L^{-3}M$	—	—	Density.
L^{-2}	—	a^2	Specific curvature of a surface.
"	—	$T \mu^{-1}$	Electric conductivity or specific electric conductance (elmg).
"	—	T^2	Coefficient of expansion (specific mass energy system).
"	—	" μ^{-1}	Electric inductive capacity; dielectric constant; specific inductive capacity; (all elmg).
"	—	" κ^{-1}	Permeability; specific magnetic inductive capacity; susceptibility; (all elst).
"	M	T^{-1} —	Thermal emissivity or immissivity (thermal and specific mass energy systems).
$L^{-\frac{3}{2}}M^{\frac{1}{2}}$	"	" $\mu^{-\frac{1}{2}}$	Current density, electric (elmg).
"	"	—	Surface density or electric displacement (elmg).
"	"	— $\kappa^{-\frac{1}{2}}$	Flux density, magnetic; magnetic induction; intensity of magnetization; (all elst).
"	"	T "	Electrochemical equivalent (elst).
"	"	" $\kappa^{-\frac{1}{2}} \theta$	Coefficient of Peltier effect (elst).
L^{-1}	—	— μ^{-1}	Reluctance or magnetic resistance (elmg).
"	—	— a	Curvature or tortuosity.
"	—	$T \mu^{-1}$	Conductance, electric; admittance; susceptance; (all elmg).
"	—	" κ^{-1}	Resistance, electric; reactance; magnetic reactance; capacity reactance or condensance; impedance; (all elst).
"	—	$T^2 \mu^{-1}$	Capacity, electric (elmg).
"	—	" κ^{-1}	Inductance; coefficient of self-induction; electrokinetic inertia; mutual inductance; permeance; magnetic capacity (all elst).
"	M	T^{-2} —	Pressure or intensity of stress; modulus of elasticity; resilience.
"	"	" θ^{-1}	Mechanical equivalent of heat (thermometric system).
"	"	T^{-1} —	Conductivity, thermal (thermal and specific mass energy systems).
$L^{-\frac{1}{2}}M^{\frac{1}{2}}$	T^{-2}	$\kappa^{\frac{1}{2}}$	Current density, electric (elst).
"	"	$T^{-1} \mu^{-\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elmg).
"	"	" $\mu^{\frac{1}{2}}$	Flux density, magnetic; magnetic induction; intensity of magnetization; (all elmg).
"	"	" $\kappa^{-\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elst).
"	"	" $\kappa^{\frac{1}{2}}$	Surface density or electric displacement (elst).
"	"	— $\mu^{\frac{1}{2}}$	Electrochemical equivalent (elmg).
"	"	— " θ	Coefficient of Peltier effect (elmg).
"	"	— $\kappa^{-\frac{1}{2}}$	Vector potential (elst).
$L^{\frac{1}{2}}M^{-\frac{1}{2}}$	—	$\mu^{-\frac{1}{2}}$	Ionic charge (elmg).

$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-2} \mu^{\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elmg).
" " " $\kappa^{\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elst).
" " $T^{-1} \mu^{-\frac{1}{2}}$	Current, electric; magnetomotive force; magnetic potential; (all elmg).
" " " $\mu^{\frac{1}{2}}$	Vector potential (elmg).
" " " $\kappa^{-\frac{1}{2}}$	Electromotive force or potential; difference of potential; coefficient of Peltier effect; (all elst).
" " " " θ^{-1}	Thermo-electric height or specific heat of electricity (elst).
" " — $\mu^{-\frac{1}{2}}$	Quantity of electricity; charge (elmg).
" " — $\kappa^{-\frac{1}{2}}$	Flux, magnetic; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elst).
L — T^{-2} —	Acceleration, linear; intensity of attraction or force at a point.
" — " κ	Reluctance or magnetic resistance (elst).
" — T^{-1} —	Velocity, linear; thermal emissivity or immissivity (thermometric system).
" — " μ	Resistance, electric; reactance; magnetic reactance; capacity reactance or condensance; impedance; (all elmg).
" — " κ	Conductance, electric; admittance; susceptance; (all elst).
" — — —	Length.
" — — μ	Inductance; coefficient of self-induction; electrokinetic inertia; mutual inductance; permeance; magnetic capacity; (all elmg).
" — — κ	Capacity, electric (elst).
" M $T^{-3} \theta^{-1}$	Conductivity, thermal (dynamical system).
" " T^{-2} —	Force.
" " T^{-1} —	Momentum or quantity of motion.
" " — —	Inertia.
$L^{\frac{3}{2}} M^{-\frac{1}{2}} T^{-1} \kappa^{\frac{1}{2}}$	Ionic charge (elst).
" $M^{\frac{1}{2}} T^{-2} \mu^{\frac{1}{2}}$	Electromotive force; potential; difference of potential; coefficient of Peltier effect; (all elmg).
" " " $\mu^{\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elmg).
" " " $\kappa^{\frac{1}{2}}$	Current; magnetomotive force; magnetic potential; (all elst).
" " $T^{-1} \mu^{\frac{1}{2}}$	Flux; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elmg).
" " " $\kappa^{\frac{1}{2}}$	Quantity of electricity, charge (elst).
" " — $\kappa^{-\frac{1}{2}} a^{-1}$	Magnetic moment (elst).
L^2 — T^{-2} —	Temperature (specific mass energy system); latent heat (dynamical and specific mass energy systems).

L^2	—	T^{-2}	κ	Reluctivity; specific reluctance (elst).
"	—	"	θ^{-1}	Mechanical equivalent of heat (thermal system).
"	—	T^{-1}	—	Conductivity, thermal (thermometric system).
"	—	"	μ	Resistivity or specific electric resistance (elmg).
"	—	—	—	Surface.
"	M	T^{-3}	—	Power or activity; electric power (elmg and elst); magnetic power (elmg and elst); rate of heat production; heat radiation; flow of heat; (all three dynamical and specific mass energy systems) flux of light.
"	"	"	a^{-2}	Intensity of light.
"	"	T^{-2}	—	Energy; work; vis-viva; impact; electric energy (elmg and elst); kinetic electric energy (elmg and elst); magnetic energy (elmg and elst) heat (dynamical and specific mass energy systems); quantity of light.
"	"	"	θ^{-1}	Entropy (dynamical system).
"	"	"	a^{-2}	Directive force (as in suspensions).
"	"	"	a^{-1}	Torque; moment; couple.
"	"	T^{-1}	"	Moment of momentum or angular momentum.
"	"	—	a^{-2}	Moment of inertia.
$L^{\frac{5}{2}}$	$M^{\frac{1}{2}}$	T^{-1}	$\mu^{\frac{1}{2}}$ a^{-1}	Magnetic moment (elmg).
L^3	M^{-1}	T^{-2}	—	Gravitation constant.
"	"	—	θ	Latent heat (thermometric system).
"	—	T^{-2}	—	Force of a centre of attraction or strength of a centre.
"	—	T^{-1}	θ	Rate of heat production; heat radiation; flow of heat; (all thermometric system).
"	—	—	—	Volume. Entropy (thermometric system).
"	—	—	θ	Heat (thermometric system).

CLASSIFIED ACCORDING TO MASS (M).

L^3	M^{-1}	T^{-2}	—	Gravitation constant.
"	"	—	θ	Latent heat (thermometric system).
$L^{\frac{1}{2}}$	$M^{-\frac{1}{2}}$	—	$\mu^{-\frac{1}{2}}$	Ionic charge (elmg).
$L^{\frac{3}{2}}$	"	T^{-1}	$\kappa^{\frac{1}{2}}$	Ionic charge (elst).
$L^{-\frac{3}{2}}$	$M^{\frac{1}{2}}$	i^{-1}	$\mu^{-\frac{1}{2}}$	Current density (elmg).
"	"	—	"	Surface density or electric displacement (elmg).
"	"	—	$\kappa^{-\frac{1}{2}}$	Flux density, magnetic; magnetic induction; intensity of magnetization; (all elst).
"	"	T	"	Electrochemical equivalent (elst).
"	"	"	θ	Coefficient of Peltier effect (elst).
$L^{-\frac{1}{2}}$	"	T^{-2}	$\kappa^{\frac{1}{2}}$	Current density (elst).
"	"	T^{-1}	$\mu^{-\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elmg).
"	"	"	$\mu^{\frac{1}{2}}$	Flux density, magnetic; magnetic induction; intensity of magnetization; (all elmg).
"	"	"	$\kappa^{-\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elst).

$L^{-\frac{1}{2}}M^{\frac{1}{2}}$	$T^{-1}\kappa^{\frac{1}{2}}$	Surface density or electric displacement (elst).
" "	$\mu^{\frac{1}{2}}$	Electrochemical equivalent (elmg).
" "	$\mu^{\frac{1}{2}} \theta$	Coefficient of Peltier effect (elmg).
" "	$\kappa^{-\frac{1}{2}}$	Vector potential (elst).
$L^{\frac{1}{2}}$	$T^{-2}\mu^{\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elmg).
" "	$\kappa^{\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elst).
" "	$T^{-1}\mu^{-\frac{1}{2}}$	Current; magnetomotive force; magnetic potential; (all elmg).
" "	$\mu^{\frac{1}{2}}$	Vector potential (elmg).
" "	$\kappa^{-\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elst).
" "	$\kappa^{-\frac{1}{2}}$	Electromotive force or potential; difference of potential; coefficient of Peltier effect; (all elst).
" "	$\mu^{-\frac{1}{2}}$	Quantity of electricity; charge; (both elmg).
" "	$\kappa^{-\frac{1}{2}}$	Flux, magnetic; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elst).
$L^{\frac{3}{2}}$	$T^{-2}\mu^{\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elmg).
" "	$\mu^{\frac{1}{2}}$	Electromotive force; potential; difference of potential; coefficient of Peltier effect; (all elmg).
" "	$\kappa^{\frac{1}{2}}$	Current; magnetomotive force; magnetic potential; (all elst).
" "	$T^{-1}\mu^{\frac{1}{2}}$	Flux, magnetic; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elmg).
" "	$\kappa^{\frac{1}{2}}$	Quantity of electricity; charge; (both elst).
" "	$\kappa^{-\frac{1}{2}} a^{-1}$	Magnetic moment (elst).
$L^{\frac{5}{2}}$	$T^{-1}\mu^{\frac{1}{2}} a^{-1}$	Magnetic moment (elmg).
$L^{-3}M$	— —	Density.
L^{-2}	T^{-1} —	Emissivity or immissivity, thermal (thermal and specific mass energy systems).
L^{-1}	T^{-2} —	Pressure or intensity of stress; resilience; modulus of elasticity.
" "	θ^{-1}	Mechanical equivalent of heat (thermodynamic system).
" "	T^{-1} —	Conductivity, thermal (thermal and specific mass energy systems).
— "	T^{-3} —	Illumination; brightness.
— "	θ^{-1}	Emissivity or immissivity, thermal (dynamical system).
— "	T^{-2} —	Surface tension.
— "	T^{-1} —	Electric deposition (elmg and elst).
— "	θ	Rate of heat production; heat radiation; flow of heat (all thermal system).
— "	— —	Mass; entropy (thermal and specific mass energy systems); capacity, thermal (dynamical, thermal, thermometric and specific mass energy systems).

---	M	---	θ	Heat (thermal system).
L	"	T^{-3}	θ^{-1}	Conductivity, thermal (dynamical system).
"	"	T^{-2}	---	Force.
"	"	T^{-1}	---	Momentum or quantity of motion.
"	"	---	---	Inertia.
L^2	"	T^{-3}	---	Power or activity; electric power (elmg and elst); magnetic power (elmg and elst); rate of heat production; heat radiation; flow of heat; (all three dynamical and specific mass energy system); flux of light.
"	"	"	a^{-2}	Intensity of light.
"	"	T^{-2}	---	Energy; work; vis-viva; impact; electric energy (elmg and elst); magnetic energy (elmg and elst); kinetic electromagnetic energy (elmg); heat (dynamical and specific mass energy system); quantity of light.
"	"	"	θ^{-1}	Entropy (dynamical system).
"	"	"	a^{-2}	Directive force (as in suspensions).
"	"	"	a^{-1}	Torque; moment; couple.
"	"	---	a^{-2}	Moment of inertia.
"	"	T^{-1}	a^{-1}	Moment of momentum or angular momentum.

CLASSIFIED ACCORDING TO TIME (T).

---	M	T^{-3}	---	Illumination; brightness.
---	"	"	θ^{-1}	Emissivity or immissivity, therm. (dynamical system).
L	"	"	"	Conductivity, thermal (dynamical system).
L^2	"	"	---	Power or activity; electric power (elmg and elst); magnetic power (elmg and elst); rate of heat production; heat radiation; flow of heat (all three dynamical and specific mass energy system); flux of light.
"	"	"	a^{-2}	Intensity of light.
L^{-1}	"	T^{-2}	---	Pressure or intensity of stress; resilience; modulus of elasticity.
"	"	"	θ^{-1}	Mechanical equivalent of heat (thermometric system).
$L^{-\frac{1}{2}}$	$M^{\frac{1}{2}}$	"	$\kappa^{\frac{1}{2}}$	Current density (elst).
---	---	"	a	Acceleration, angular.
---	M	"	---	Surface tension.
$L^{\frac{1}{2}}$	$M^{\frac{1}{2}}$	"	$\mu^{\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elmg).
"	"	"	$\kappa^{\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elst).
L	---	"	---	Acceleration, linear; intensity of attraction or force at a point.
"	---	"	κ	Reluctance or magnetic resistance (elst).
"	M	"	---	Force.
$L^{\frac{3}{2}}$	$M^{\frac{1}{2}}$	"	$\mu^{\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elmg).

$L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-2} \mu^{\frac{1}{2}}$	Electromotive force; potential; difference of potential; coefficient of Peltier effect; (all elmg).
" " " $\kappa^{\frac{1}{2}}$	Current; magnetomotive force; magnetic potential; (all elst).
L^2 — " —	Temperature (specific mass energy system); square of a velocity; latent heat (dynamical and specific mass energy system).
" — " κ	Reluctivity; specific reluctance (both elst).
" — " θ^{-1}	Mechanical equivalent of heat (thermal system).
" M " —	Energy; work; vis-viva; impact; electric energy (elmg and elst); magnetic energy (elmg and elst); kinetic electromagnetic energy (elmg); heat (dynamical and specific mass energy systems); quantity of light.
" " " θ^{-1}	Entropy (dynamical system).
" " " a^{-2}	Directive force (as in suspensions).
" " " a^{-1}	Torque; moment; couple.
$L^3 M^{-1}$ —	Gravitation constant.
" — " —	Force of a centre of attraction or strength of a centre.
$L^{-2} M T^{-1}$ —	Emissivity or immissivity, thermal (thermal and specific mass energy systems).
$L^{-\frac{3}{2}} M^{\frac{1}{2}}$ " $\mu^{-\frac{1}{2}}$	Current density (elmg).
$L^{-1} M$ " —	Conductivity, thermal (thermal and specific mass energy systems).
$L^{-\frac{1}{2}} M^{\frac{1}{2}}$ " $\mu^{-\frac{1}{2}}$	Field intensity, magnetic; magnetizing force; (both elmg).
" " " $\mu^{\frac{1}{2}}$	Flux density, magnetic; intensity of magnetization; magnetic induction; (all elmg).
" " " $\kappa^{-\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elst).
" " " $\kappa^{\frac{1}{2}}$	Surface density or electric displacement (elst).
— — " —	Frequency (elmg and elst).
— — " κ	Conductivity or specific electric conductance (elst).
— — " a	Velocity, angular.
— M " —	Electric deposition (elmg and elst).
— " " θ	Rate or heat production; heat radiation; flow of heat; (all thermal system).
$L^{\frac{1}{2}} M^{\frac{1}{2}}$ " $\mu^{-\frac{1}{2}}$	Current; magnetomotive force; magnetic potential; (all elmg).
" " " $\mu^{\frac{1}{2}}$	Vector potential (elmg).
" " " $\kappa^{-\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elst).
" " " $\kappa^{-\frac{1}{2}}$	Electromotive force or potential; difference of potential; coefficient of Peltier effect; (all elst).
L — " —	Velocity, linear; emissivity or immissivity, thermal (thermometric system).
" — " μ	Resistance, electric; impedance; reactance; magnetic reactance; capacity reactance or condensance; (all elmg).

L	---	T^{-1}	κ	Conductance, electric; admittance, susceptance; (all elst).
"	M	"	---	Momentum or quantity of motion.
$L^{\frac{3}{2}}$	$M^{-\frac{1}{2}}$	"	$\kappa^{\frac{1}{2}}$	Ionic charge (elst).
"	$M^{\frac{1}{2}}$	"	$\mu^{\frac{1}{2}}$	Flux, magnetic; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elmg).
"	"	"	$\kappa^{\frac{1}{2}}$	Quantity of electricity; charge (both elst).
L^2	---	"	---	Conductivity, thermal (thermometric system).
"	---	"	μ	Resistivity or specific electric resistance (elmg).
"	M	"	α^{-1}	Moment of momentum or angular momentum.
$L^{\frac{5}{2}}$	$M^{\frac{1}{2}}$	"	$\mu^{\frac{1}{2}}$	Magnetic moment (elmg).
L^3	---	"	θ	Rate of heat production; heat radiation; flow of heat; (all thermometric system).
L^{-2}	---	T	μ^{-1}	Conductivity or specific electric conductance (elmg).
$L^{-\frac{3}{2}}$	$M^{\frac{1}{2}}$	"	$\kappa^{-\frac{1}{2}}$	Electrochemical equivalent (elst).
"	"	"	$\kappa^{-\frac{1}{2}}$	Coefficient of Peltier effect (elst).
L^{-1}	---	"	μ^{-1}	Conductance, electric; admittance; susceptance; (all elmg).
"	---	"	κ^{-1}	Resistance, electric; impedance; reactance; magnetic reactance; capacity reactance or condensation; (all elst).
"	---	"	---	Time; period (elmg and elst); time constant (elmg and elst).
---	---	"	κ^{-1}	Resistivity or specific electric resistance (elst).
L^{-2}	---	T^2	---	Coefficient of expansion (specific mass energy system).
"	---	"	μ^{-1}	Electric inductive capacity; dielectric constant; specific inductive capacity; (all elmg).
"	---	"	κ^{-1}	Permeability or specific magnetic inductive capacity; susceptibility; (both elst).
L^{-1}	---	"	μ^{-1}	Capacity (elmg).
"	---	"	κ^{-1}	Inductance or coefficient of self-induction; electrokinetic inertia; mutual inductance; permeance; magnetic capacity; (all elst).

CLASSIFIED ACCORDING TO MAGNETIC PERMEABILITY (μ).

L^{-2}	---	T	μ^{-1}	Conductivity or specific electric conductance (elmg).
"	---	T^2	"	Electric inductive capacity; dielectric constant; specific inductive capacity; (all elmg).
L^{-1}	---	---	"	Reluctance or magnetic resistance (elmg).
"	---	T	"	Conductance, electric; admittance; susceptance; all elmg).
"	---	T^2	"	Capacity (elmg).
---	---	---	"	Reluctivity; specific reluctance; (both elmg).
$L^{-\frac{3}{2}}$	$M^{\frac{1}{2}}$	T^{-1}	$\mu^{-\frac{1}{2}}$	Current density (elmg).
"	"	---	"	Surface density or electric displacement (elmg).
$L^{-\frac{1}{2}}$	"	T^{-1}	"	Field intensity, magnetic; magnetizing force; (both elmg).

$L^{\frac{1}{2}} M^{-\frac{1}{2}} \mu^{-\frac{1}{2}}$	Ionic charge (elmg).
$“ M^{\frac{1}{2}} T^{-1} “$	Current; magnetomotive force; magnetic potential (all elmg).
$“ “ — “$	Quantity of electricity; charge; (both elmg).
$L^{-\frac{1}{2}} M^{\frac{1}{2}} T^{-1} \mu^{\frac{1}{2}}$	Flux density, magnetic; intensity of magnetization magnetic induction; (all elmg).
$“ “ — “$	Electrochemical equivalent (elmg).
$“ “ — “ \theta$	Coefficient of Peltier effect (elmg).
$L^{\frac{1}{2}} “ T^{-2} \mu^{\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elmg).
$“ “ T^{-1} “$	Vector potential (elmg).
$L^{\frac{3}{2}} “ T^{-2} “ \theta^{-1}$	Thermo-electric height or specific heat of electricity (elmg).
$“ “ “ \mu^{\frac{1}{2}}$	Electromotive force; potential; difference of potential; coefficient of Peltier effect; (all elmg).
$“ “ T^{-1} \mu^{\frac{1}{2}}$	Flux, magnetic; magnetic lines of force; strength of pole; quantity of magnetism; electrokinetic momentum; (all elmg).
$L^{\frac{5}{2}} “ “ “ a^{-1}$	Magnetic moment (elmg).
$— — — \mu$	Magnetic permeability; permeability or specific magnetic inductive capacity; susceptibility; (all elmg).
$L — T^{-1} “$	Resistance, electric; impedance; reactance; magnetic reactance; capacity reactance or condensance; (all elmg).
$“ — — “$	Inductance or coefficient of self-induction; electrokinetic inertia; mutual inductance; permeance; magnetic capacity; (all elmg). *
$L^2 — T^{-1} “$	Resistivity or specific electric resistance (elmg).

 CLASSIFIED ACCORDING TO ELECTRIC INDUCTIVE CAPACITY (κ).

$L^{-2} — T^2 \kappa^{-1}$	Permeability or specific magnetic inductive capacity; susceptibility; (all elst).
$L^{-1} — T “$	Resistance, electric; impedance; reactance; magnetic reactance; capacity reactance or condensance; (all elst).
$“ — T^2 “$	Inductance or coefficient of self-induction; electrokinetic inertia; mutual inductance; permeance; magnetic capacity; (all elst).
$— — T “$	Resistivity or specific electric resistance (elst).
$L^{-\frac{3}{2}} M^{\frac{1}{2}} — \kappa^{-\frac{1}{2}}$	Flux density, magnetic; magnetic induction; intensity of magnetization; (all elst).
$“ “ T “$	Electrochemical equivalent (elst).
$“ “ “ “ \theta$	Coefficient of Peltier effect (elst).
$L^{-\frac{1}{2}} “ T^{-1} \kappa^{-\frac{1}{2}}$	Intensity of electric field; electromotive force at a point; (both elst).
$“ “ — “$	Vector potential (elst).
$L^{\frac{1}{2}} “ T^{-1} “$	Electromotive force or potential; difference of potential; coefficient of Peltier effect; (all elst).

$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1} \kappa^{-\frac{1}{2}} \theta^{-1}$	Thermo-electric height or specific heat of electricity (elst).
" " — "	Flux, magnetic; magnetic lines of force, strength of pole; quantity of magnetism; electrokinetic momentum; (all elst).
$L^{\frac{3}{2}}$ " — $\kappa^{-\frac{1}{2}} \alpha^{-1}$	Magnetic moment (elst).
$L^{-\frac{1}{2}}$ " $T^{-2} \kappa^{\frac{1}{2}}$	Current density (elst).
" " T^{-1} "	Surface density or electric displacement (elst).
$L^{\frac{1}{2}}$ " T^{-2} "	Field intensity, magnetic; magnetizing force; (both elst).
$L^{\frac{3}{2}}$ $M^{-\frac{1}{2}} T^{-1}$ "	Ionic charge (elst).
" $M^{\frac{1}{2}} T^{-2}$ "	Current; magnetomotive force; magnetic potential; (all elst).
" " T^{-1} "	Quantity of electricity, charge (elst).
— — — κ	Electric inductive capacity; dielectric constant; specific inductive capacity; (all elst).
— — T^{-1} "	Conductivity or specific electric conductance (elst).
L — T^{-2} "	Reluctance or magnetic resistance (elst).
" — T^{-1} "	Conductance, electric; admittance; susceptance; (all elst).
" — — "	Capacity (elst).
L^2 — T^{-2} "	Reluctivity; specific reluctance (elst).

CLASSIFIED ACCORDING TO TEMPERATURE (θ).

$L^{-1} M T^{-2} \theta^{-1}$	Mechanical equivalent of heat (thermometric system).
$L^{\frac{1}{2}} M^{\frac{1}{2}} T^{-1}$ " $\kappa^{-\frac{1}{2}}$	Thermo-electric height or specific heat of electricity (elst).
— — — θ^{-1} *	Coefficient of expansion (dynamical, thermal and thermometric systems).
— $M T^{-3}$ "	Emissivity or immissivity, thermal (dynamical system).
L " " "	Conductivity, thermal (dynamical system).
$L^{\frac{3}{2}} M^{\frac{1}{2}} T^{-2}$ " $\mu^{\frac{1}{2}}$	Thermo-electric height or specific heat of electricity (elmg.)
L^2 — " θ^{-1}	Mechanical equivalent of heat (thermal system).
" M " "	Entropy (dynamical system).
$L^{-\frac{3}{2}} M^{\frac{1}{2}} T \theta$ $\kappa^{-\frac{1}{2}}$	Coefficient of Peltier effect (elst).
$L^{-\frac{1}{2}}$ " — " $\mu^{\frac{1}{2}}$	Coefficient of Peltier effect (elmg.).
— — — θ	Temperature (thermal, thermometric and dynamical systems); latent heat (thermal system).
— $M T^{-1}$ "	Rate of heat production; heat radiation; flow of heat; (all thermal system).
— " — "	Heat (thermal system).
$L^3 M^{-1}$ — "	Latent heat (thermometric system).
" — T^{-1} "	Rate of heat production; heat radiation; flow of heat; (all thermometric system).
" — — "	Heat (thermometric system).

CLASSIFIED ACCORDING TO ANGLE (a).

L^2	M	T^{-3}	a^{-2}	Intensity of light.
"	"	T^{-2}	"	Directive force (as in suspensions).
"	"	—	"	Moment of inertia.
$L^{\frac{3}{2}}$	$M^{\frac{1}{2}}$	—	a^{-1}	Magnetic moment (elst).
L^2	M	T^{-2}	"	Torque; moment; couple.
"	"	T^{-1}	"	Moment of momentum or angular momentum.
$L^{\frac{5}{2}}$	$M^{\frac{3}{2}}$	"	"	Magnetic moment (elmg).
L^{-1}	—	—	a	Curvature or tortuosity.
—	—	T^{-2}	"	Acceleration, angular.
—	—	T^{-1}	"	Velocity, angular.
—	—	—	"	Angle, plane.
L^{-2}	—	—	a^2	Specific curvature of a surface.
—	—	—	"	Angle, spherical.

CLASSIFIED ACCORDING TO NO-DIMENSIONAL QUANTITIES.

Number.....	Specific gravity. Specific heat (dynamical thermometric, thermal and specific mass energy systems). Mechanical equivalent of heat (dynamical and specific mass energy systems). Electric inductive capacity; dielectric constant; specific inductive capacity; inductance factor; (all elmng). Electric inductive capacity; dielectric constant; specific inductive capacity; (all elst). Efficiency; power factor; angle, plane; angle, solid.
Number $\times \mu^{-1}$	Reluctivity; specific reluctance; (elmng).
Number $\times \mu$	Permeability or specific magnetic inductive capacity; susceptibility; (both elmng).
Number $\times \kappa$	Electric inductive capacity; dielectric constant; specific inductive capacity; (all elst).

INTEGRITY OF TESTS OF METALS.

BY

ALEXANDER E. OUTERBRIDGE, JR.,

Professor of Metallurgy in Franklin Institute.

[This paper was intended as the opening address at the annual autumn sessions of the Mining and Metallurgical Section, but is printed in advance by permission of the author.]

THERE is no subject of greater interest and importance in the metallurgical arts than that of testing metals. Upon the integrity of these tests rests the stability of all the immense modern structures composed of iron, steel, bronze and other metals; human life depends in many instances upon the reliability of tests made in the laboratories of 'coupons' cut from full size sections, in some cases, or from small bars,—usually cast attached to larger masses,—in other cases.

These coupons, or test-pieces, are supposed to fairly represent the average tensile and transverse strength, the ductility or resilience (*i.e.*, ability to resist shock), the micro-structure of the metal and, in a word, to reveal the true physical properties of the material entering into any given structure.

Have we arrived at a degree of perfection in the art of testing metals that enables us to rely with confidence upon such records? I fear not, and I purpose herein to give briefly a few of my reasons for this somewhat pessimistic view.

So far as the development of various machines for accurately testing the tensile strength, transverse strength, torsional strains, and so forth, of metals, is concerned, a very high degree of sensitiveness combined with accuracy, has been arrived at by many constructors of such apparatus, but if the specimens tested do not in all cases fairly represent the quality of the material in the mass the records may be, and often are, misleading.

My own investigations, extending over a period of nearly forty years, have convinced me that coupons or test-pieces do not always represent truly the strength, molecular structure, resilience, etc., of the material to which they may be attached

and to which they are supposed to conform closely in physical properties for the following reasons among others.

Metals in their pure state are not employed in engineering constructions, all are more or less heterogenous compounds, or alloys, and all alloys (with perhaps a single exception, viz., gold and copper) tend to 'segregate' or separate in the process of cooling from the liquid to the solid condition into richer and poorer alloys, one particular combination usually forming what is known technically as the 'eutectic.' For example the standard alloy of silver and copper (nine parts silver, one part copper) used for the silver coin of the United States Government and of many other nations, is, of course, prepared with the greatest care, and the molten metal is thoroughly stirred before it is poured into 'ingots.'

These ingots are made of the proper width and thickness to enable them to be rolled into strips from which the blanks or 'planchets' for the coin are punched. If an assay be made from chips or filings cut from the centre of a silver dollar and an assay also be made from chips cut from the periphery, they will not agree exactly; indeed cases have been known where the variation in 'fineness' actually exceeded the legal limit of 'tolerance' or allowance of variation from the standard of 'nine-tenths fine.'

This fact was proven by exhaustive investigations, made many years ago, which resulted in the abandonment of the old method of taking test-pieces by cutting chips from the ingots, or from the blanks, and substituting therefor what is known as the 'granulation test method.' After the melted alloy has been thoroughly 'rabbled' or stirred, two or more samples of the liquid metal are dipped out from the pot and poured into ice water in order to cool them instantly in the form of granules. Under these conditions there is not time for segregation to occur, and duplicate samples taken from the top and bottom of a crucible containing perhaps 7000 to 10,000 Troy ounces of coin metal will agree in fineness within a few thousandths of one per cent.

In the case of the standard gold alloy for coin (nine parts gold, one part copper) no precautions of this kind are needed, for the simple reason that this alloy does not segregate, and chips taken from the edge and from the centre of a double-eagle will

conform to the legal requirements, notwithstanding that they are very much more strict than in the case of silver coin.

An experience of twelve years as an assistant in the Assay Laboratory of the United States Mint (1868-1880) made me familiar with these refinements in metallurgical methods of testing that have been of inestimable value in my after life, which has been devoted to testing commercial metals. The knowledge thus gained has been practically applied in various ways in connection with cast-iron, steel and bronzes.

With respect to cast-iron it is no exaggeration to say that the rate of cooling of gray cast-iron exerts as important an influence in determining its physical properties as does variation of its chemical constituents within, of course, certain quite wide limits. If a wedge-shaped bar be cast of ordinary foundry iron, say six feet long, six inches wide, six inches thick at one end, and tapering in thickness to, say one-quarter inch thick, almost every grade of cast-iron may be found in the bar by nicking and breaking it into short sections, say six inches long each. At the thick end the fracture will be coarse grained or 'open' with very dark color due to the fact that almost all of the carbon is in the graphitic or 'free' condition. At the thin end the fracture will be fine grained and light in color because a considerable portion of the carbon will be chemically combined with the iron. If test-bars be cut from these different sections, it will be observed that the coarse-grained metal is very soft under the tool, while test-bars cut from near the thin end will be very hard to turn. Between these two extremes the metal will have intermediate degrees of hardness and of coarse grainedness.

If tensile tests be made from different portions of the casting, it will be found that the strength varies with the structure through an enormous range, as much as 100 per cent. gain often occurring in one portion over another. If the ordinary foundry iron used for the wedge-shaped casting be low in silicon (say 1 per cent. or under) the thin end of the wedge will be as white as silver, as hard as steel and as brittle as glass, because a large proportion of the carbon will then be in the combined form.

I have before me two test-bars of soft foundry iron used for casting light pulleys, poured from one small hand-ladle of

iron into companion bars of the same size, viz., 1 in. x 1 in. x 15 in.; one bar was cooled normally in the 'green' sand mold, the other was cooled very rapidly indeed. Both bars were broken transversely on an ordinary transverse testing machine, using a span of 12 inches. One bar, cooled normally, broke under a strain of 2000 pounds (round figures); the other, cooled rapidly, at 4000 pounds exactly. One-half of each bar was then used for tensile tests, being turned to the same dimensions and pulled upon a 100,000 pound hydraulic testing machine. The bar cooled normally showed tensile strength of 21,500 pounds per square inch. The bar cooled rapidly showed tensile strength of 37,000 pounds per square inch. These particular tests were made twenty-two years ago and the results have been corroborated many times since then, also valuable practical use has been made continuously from that time of the knowledge thus gained of the remarkable effect of controlling the cooling of castings of non-uniform sections.

In a paper giving some of the foregoing facts, read before the American Society for Testing Materials in 1903 published in their *Proceedings*, vol. iii, p. 216, the following conclusions were drawn:

"The rate of cooling of cast-iron from the fluid to the solid state is such an important factor in determining the physical properties of the metal, that it is just as necessary to know the dimensions of the test-bars as it is to know the chemical composition. For the same reason it is equally desirable that standard sizes of test-bars should be adopted, which would be suitable for different grades of iron."

It is pleasing to note that the American Society for Testing Materials has, through one of its sub-committees, been endeavoring to bring about uniformity of methods of testing, not only between different manufacturers in the United States, but also in Europe as well, with indications of a successful issue in time.

Castings of iron and other metals are frequently made for the Government as well as for private engineering firms under specifications which sometimes tax the ability of the founder to meet pretty stiff requirements as to strength. In the absence of any specific rules as to the method of molding the test-bars or coupons, or even as to their size, the temptation to a foundry foreman, who may have practical knowledge of

the facts here noted, to 'jockey' with the test-bars and thus insure that they will fully meet the requirements, is very great, and ought not in the interest of all to be continued longer.

There is still another method, now pretty well known, by which the transverse strength of cast-iron test-bars can be increased from 25 per cent., even up to nearly 50 per cent., without either rapid cooling of the metal or making any change in method of molding. Instead of simply brushing off the loose sand from the test-bars with a wire scratch-brush if they be placed in a 'tumbling barrel,' commonly employed in foundries for cleaning castings and tumbled about therein for a couple of hours, they will all gain largely in transverse strength due, it is thought partly, if not mainly, to the rapid release of 'cooling strains' caused by shocks, and it has long been known that iron-castings improve in strength with age, due to gradual release of internal strains. When these peculiar observations were first made known, the custom of cleaning the sand from test-bars in the tumbling barrel became very popular indeed and finally a few years ago the American Society for Testing Materials found it desirable to incorporate a special clause in its new specifications for cast-iron that test-bars must not be tumbled or otherwise subjected to mechanical shocks or vibrations before being broken. This was a gratifying tribute to the original discovery.

On the occasion of a visit to a large manufacturing establishment sometime before this restricting clause was adopted I noticed that all of the cast-iron transverse test-bars had been put through the tumbling mill 'to clean them' as I was informed by the boss.

With regard to test-bars for bronze castings, similar restrictions should apply in regard to cooling, for segregation occurs in all commercial bronzes, depending largely upon the rate of cooling from the liquid to the solid state. This segregation changes the molecular structure and affects the tensile strength of the metals. Coupons or test-pieces of bronze cooled much more rapidly than the castings to which they may be attached do not reveal the true character of the fracture, or the real strength of the metal. On the contrary they present to the eye a finer grained, more uniform metal and show abnormal strength in the testing machine. Very recently indeed my attention was called to a novel application of this fact by noticing some rather high

tensile tests of test-bars attached to some important castings made of a special bronze. The fracture of the test-pieces was exceedingly fine grained and showed an absolutely uniform or homogeneous structure. On examining very carefully some of the castings with the test-bars still attached, it was plainly to be seen that they were poured under very different conditions from the castings themselves, the test-bars being cast into iron molds so as to solidify them instantly, while the casting to which they were joined were made in ordinary sand molds.

Test-bars thus doctored are, in my judgment, far worse than useless, since they give the purchaser of the castings, who has taken the precaution (involving some trouble and expense) of turning and testing coupons, a false record of the character of the metal in his castings.

Apropos of this, I will venture, in conclusion, to refer to my short paper entitled "A Study of the Micro-Structure of Bronzes," printed in the JOURNAL OF THE FRANKLIN INSTITUTE, January, 1899, in which appear a number of photomicrographs of specimens of bronze metals (ninety were used in the investigation) cast in sand, and one representing a U. S. cent in which the crystals are very much finer and the metal is apparently more homogeneous, for there is an absence of the irregular bands of the eutectic alloy so conspicuous in all of the other bronze specimens. It was stated that: "This is perhaps partly owing to the fact that coin ingots are always cast in iron molds and the metal is thus suddenly solidified while all of the other specimens were cast in sand molds. This observation may have practical value."

The conclusions drawn from these investigations with bronze metals were quite similar to those already noted with respect to investigations in cast-iron, and are as follows:

1. Variations in treatment of specimens cause variations in the results, which may be misleading, and it would, therefore, seem desirable that some uniform system should be adopted by all investigators in this field.

2. The rate of cooling of a mass of metal affects the micro-structure so that two specimens from the same ladle of metal, one taken from a small casting quickly cooled, the other from a large casting slowly cooled; or two photomicrographs taken from different portions of the same specimen, may show variations in micro-structure that may lead to error.

It is desirable, therefore, that some uniform size of specimens (and uniform method of molding) should be selected by micro-metallurgists as a standard with which to make comparisons.

The actual case cited here, where bronze castings were made in sand molds subject to slow cooling, while the attached coupons for testing were made in iron molds to ensure rapid cooling, coming to my notice only a few days ago emphasizes the importance of some concerted action in accordance with the foregoing suggestions looking toward adoption of standard methods for testing metals, and for ensuring the integrity of such tests.

Numerous other illustrations might be drawn from my own daily experience and observation, but I think enough have been given to establish a good case. It is one that I have been arguing for a number of years.

Magnetic and Electrical Properties of Iron-Silicon Alloys.

C. F. BURGESS and J. ASTON. (*Met. and Chem. Eng.*, 1910, viii.)—It was shown in 1901 that certain iron alloys made by Hadfield, containing $2\frac{1}{4}$ per cent. of aluminum or $2\frac{1}{2}$ per cent. of silicon, had magnetic permeabilities exceeding that of pure iron. The authors have shown that similar results are obtained with irons containing 2 per cent. of tin or 4 per cent. of arsenic. The improvement in the magnetic qualities appears to be due to some change in the physical structure of the iron rather than to a chemical effect. Annealing at such a temperature as will remove the cooling and forging strains improves the entire magnetization curve of pure iron, while annealing at a high temperature deteriorates the quality with high and improves the permeability with low magnetizing forces. The authors investigated the magnetic properties of a number of iron-silicon alloys containing from 0.2 to 4.6 per cent. silicon, in comparison with a bar of very pure electrolytic iron. Unannealed, all fall below the standard bar, those containing the least silicon giving the best results. Annealing at 675° C. improved the results. Annealing at 1000° C. decreased the permeability of bars with low silicon, but improved bars of high silicon. The effect of silicon seems more pronounced in the presence of certain impurities. Silicon steels have a high electrical resistance which prevents eddy currents. With the addition of 4.66 per cent. silicon the alloy has a minimum hysteresis loss and an electrical resistance more than five times that of the electrolytic standard.

THE TEMPERATURE COEFFICIENT OF RESISTANCE OF COPPER.*

BY
J. H. DELLINGER.

THE values in common use for the temperature coefficient of copper vary from $a_0 = 0.00398$ to 0.00445 , or $a_{20} = 0.00369$ to 0.00409 (a_0 and a_{20} are defined respectively by the equations: $R_t = R_0 (1 + a_0 t)$, and $R_t = R_{20} (1 + a_{20} [t - 20])$, in which $t =$ any temperature Centigrade, and R_0 , R_{20} , $R_t =$ resistance respectively at 0°C. , at 20°C. , and at $t^\circ \text{C.}$). The differences in these various values assumed as standard may be considered to be due either to errors of the measurements made in establishing them, or to differences in the temperature coefficients of different samples of copper. In either case, accurate results cannot be expected when one of these values is taken as fixed and used for all samples. That this fact is not recognized is shown by the common practice of assuming that the temperature coefficient is the same for different samples of copper, while the conductivity is usually measured. It was accordingly considered of importance to determine whether the temperature coefficient of different samples does vary, and also to find whether there is any simple relation between the conductivity and the temperature coefficient.

This investigation has shown that there are variations of the temperature coefficient, and that to a fair accuracy the relation of conductivity to temperature coefficient is a simple proportionality. Thus, annealing is known to increase the conductivity of hard-drawn wire; it was found that annealing increases the temperature coefficient by an exactly proportionate amount. Samples varying in the amount of chemical impurities are known to vary in conductivity; it was found that the temperature coefficient was substantially proportional to the conductivity.

Samples were investigated from 14 of the most important copper refiners and wire manufacturers, in this country, Ger-

* Abstract of a paper to appear in Bulletin of the Bureau of Standards, vol. 7.

TABLE.

TEMPERATURE COEFFICIENTS (1) OBSERVED, AND (2) COMPUTED, FOR COPPER OF 100 PER CENT. CONDUCTIVITY.

* Percent conductivity	$\frac{\alpha_{20}}{Rt - R_{20}} = \frac{R_{20}[t - 20]}{R_{20}[t - 20]}$	$\frac{C}{\left(= \frac{\alpha_{20}}{\text{Percent conductivity}} \right)}$	Mean values of $\frac{C}{C}$	Deviations from final mean
† 97.44	0.00384 ₀	0.00394 ₁	0.00394 ₂	+ 0 ₄
† 97.46	0.00384 ₃	0.00394 ₃		
† 97.54	0.00384 ₆	0.00394 ₃		
100.22	0.00395 ₀	0.00394 ₁		
100.24	0.00395 ₂	0.00394 ₃		
100.29	0.00395 ₄	0.00394 ₃		
100.44	0.00395 ₉	0.00394 ₂	0.00392 ₆	- 1 ₂
† 97.47	0.00382 ₃	0.00392 ₄		
100.11	0.00393 ₁	0.00392 ₇		
99.96	0.00392 ₇	0.00392 ₉		
100.09	0.00392 ₉	0.00392 ₆	0.00393 ₀	- 0 ₈
† 98.18	0.00386 ₀	0.00393 ₂		
† 98.25	0.00386 ₀	0.00392 ₉		
99.73	0.00393 ₅	0.00394 ₆	0.00393 ₈	0 ₁
100.16	0.00393 ₆	0.00393 ₀		
† 96.56	0.00380 ₆	0.00394 ₂	0.00393 ₇	- 0 ₁
† 96.96	0.00382 ₈	0.00394 ₈		
99.63	0.00391 ₇	0.00393 ₂		
99.97	0.00392 ₇	0.00392 ₈		
† 94.13	0.00371 ₆	0.00394 ₈	0.00394 ₉	+ 1 ₁
† 95.80	0.00378 ₂	0.00394 ₈		
96.60	0.00381 ₃	0.00394 ₀		
99.89	0.00394 ₆	0.00395 ₀		
† 97.07	0.00384 ₀	0.00395 ₃	0.00395 ₂	+ 1 ₄
99.75	0.00394 ₀	0.00395 ₀		
† 97.96	0.00385 ₃	0.00393 ₃	0.00393 ₂	- 0 ₈
100.70	0.00395 ₉	0.00393 ₂		
99.14	0.00392 ₆	0.00396 ₀	0.00395 ₆	+ 1 ₈
99.39	0.00392 ₈	0.00395 ₂		
† 96.95	0.00383 ₀	0.00395 ₀	0.00394 ₃	+ 0 ₈
100.26	0.00394 ₆	0.00393 ₆		
† 97.84	0.00385 ₀	0.00393 ₃	0.00393 ₂	- 0 ₆
100.54	0.00395 ₁	0.00393 ₀		
† 97.25	0.00382 ₈	0.00393 ₆	0.00393 ₄	- 0 ₄
100.14	0.00393 ₈	0.00393 ₃		
† 97.75	0.00384 ₃	0.00393 ₃	0.00393 ₁	- 0 ₇
100.70	0.00395 ₇	0.00392 ₉		
Final mean.....			0.00393 ₃	= 0 ₈
Final mean rounded off.....			0.00394	= 0.2%

* 100% conductivity corresponds to resistivity of 0.153022 ohm per metregramme (or 1.72128 micro-ohms per centimetre cube, density = 8.89), at 20°C.

† Hard-drawn wires; the others are annealed.

many, France, and Austria. The range of conductivity of the samples covered thoroughly the range of the copper furnished to the electrical industry.

The experimental work was carried out with wires, most of which were No. 12, B. & S. gauge about 120 cm. long. The resistivity and percent conductivity were computed from measurements of the length, mass, and resistance. The resistivity is given in "ohms per metre-gramme" by multiplying the resistance per metre by the mass per metre. The "percent conductivity" is calculated on the assumption that 100 percent conductivity corresponds to the arbitrary standard resistivity of 0.153022 ohm per metre-gramme at 20° C. The resistance measurements were made in a specially designed apparatus, by the Thomson bridge method. Temperatures were measured with a mercury-in-glass thermometer. The accuracy of the resulting conductivity values is estimated as within 0.03 per cent., and of the temperature coefficient values within 0.000004, or 0.1 per cent. To an accuracy of 0.2 per cent., the temperature coefficient was found to be linear between 10° C. and 100° C. The results of the measurements on the separate samples are given in the table above. For each sample, α_{20} is divided by the percent conductivity and the quotient given under C . C , the constant resulting, is the computed value of the temperature coefficient of copper of 100 percent conductivity.

The agreement of C for samples differing in physical condition is shown by the first and other groups. This agreement was further established by special annealing and drawing experiments.

The effect of bending and winding of wires was also investigated. Any distortion of an annealed wire is known to produce local hardening and increase of resistance. It was found that much the greater part of this increase was due to local changes of cross-section and not to the change of resistivity. This was shown by the fact that while the *apparent* conductivity decreased, the temperature coefficient changed practically not at all. This having been established for cases of bending and distortion more severe than those arising in ordinary practice, it may accordingly be assumed without serious error that the temperature coefficient of a copper wire is the same after winding on a machine or instrument as it was before. Accordingly, if a measurement

has been made of either the conductivity or the temperature coefficient of the wire before winding, the temperature coefficient may safely be assumed to be known after winding, and may be used in the calculation of temperature rise.

The main result of this investigation may be expressed in the form of the following practical rule: *The 20° C. temperature coefficient of a sample of copper is given by multiplying the number expressing the percent conductivity decimally by 0.00394.* The rule can be put in a remarkably convenient form for reducing the results of conductivity measurements to a standard temperature, viz.: *the change of the resistivity per degree C. of a sample of copper is 0.000598 ohm per metre-gramme or 0.00681 micro-ohm per centimetre cube.* The last two constants are independent both of the temperature of reference and of observation, and also independent of the sample of copper.

The foregoing results indicate that the measurement of conductivity may often be replaced by a measurement of the temperature coefficient. Four particular cases suggest themselves in which the measurement of temperature coefficient has considerable advantage over a conductivity measurement: (1) *Odd shapes.* Unless a uniform sample can be prepared, the determination of conductivity directly is hopeless. (2) *Short samples,* for which the difficulty of measurement of the dimensions and the possible uncertainty of the current distribution limit the applicability of conductivity measurement. (3) *Wires that have been distorted or bent.* As shown above, the apparent conductivity of a distorted wire is incorrect, while the temperature coefficient is not materially changed. (4) *The estimation of chemical purity,* of which the conductivity is a familiar criterion. Evidently the temperature coefficient is fully as reliable a criterion as the conductivity, and is more generally applicable, and is often an easier test to apply than either the conductivity or chemical determinations.

ATOMIC WEIGHTS—AN HISTORICAL SKETCH.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S.

[This paper reviews the fundamental laws underlying atomic weight determinations. A sketch is given of the work of Dalton, Berzelius and Stas upon these constants of nature. A description is given of the schools of chemists which have carried out atomic weight determinations at the University of Pennsylvania under E. F. Smith and at Harvard University under T. W. Richards.]

AT the beginning of the nineteenth century, John Dalton¹ applied the ancient Greek philosophical theory of atoms,—the theory of Leucippus and Democritus,—as an explanation of his own laws of definite and multiple proportions, and thus founded the chemical atomic theory. Dalton then determined the 'relative' or atomic weights of the elements; in his "New System of Chemical Philosophy," Dalton took hydrogen as the unit with which he compared the other elements. He did not distinguish between atoms and molecules, hence his table contains atomic weights for water, ammonia and other compounds. Moreover Dalton had no means for ascertaining the number of atoms in a molecule, so he assumed that the atom (our molecule) of water consists of one atom of hydrogen and one atom of oxygen, whence the atomic weight of oxygen is given as 7, less than one-half of our value 16.

The study of atomic weights was aided greatly by the discovery of certain laws. In 1808 Gay Lussac and Humboldt deduced the law of combination by volume of gases. "When two or more gaseous substances combine to form a gaseous compound, the volumes of the individual constituents as well as their sum bear a simple relation to the volume of the compound,"² provided that the gases be under the same conditions of temperature and pressure. This law and the laws of Boyle and Charles have been used by Avogadro and Ampère,³ and, later on, by Canizzaro as the basis of the molecular theory.

In 1819 Dulong and Petit announced the law of specific heats; the product of the specific heat of an element times its atomic

weight always gives approximately the same constant 6.25, *i.e.*, all the elements have approximately the same atomic heat. In 1831 Neumann and Regnault discovered that the molecular heat of a compound is a multiple of the atomic heat directly proportional to the number of atoms in the molecule, *e.g.*, lead chloride PbCl_2 contains 3 atoms in its molecule, and has a molecular heat of 18.45, about three times 6.25.

Mitscherlich deduced the law of isomorphism in 1819. "The same number of atoms combined in the same manner produce the same crystalline form, the latter being independent of the chemical nature of the atoms, and determined solely by their number and arrangement."⁴ However barium permanganate and sodium sulphate are isomorphous in the sense that they possess the same crystalline form, yet they differ from each other in respect to the number of atoms in the molecule. Kopp⁵ has found that compounds which have the same number of atoms, arranged in the same manner in the molecule and possess the same crystalline form,—isomorphous compounds according to Mitscherlich,—are characterized by the property of forming overgrowths, *e.g.*, a crystal of one alum will grow in the solution of another alum.

Within recent years, the Periodic Law of Lothar Meyer and Mendelejeff⁶ has been helpful in determining the correct values of atomic weights. This law states that the properties of the elements are periodic functions of their atomic weights.

Berzelius devoted his life to atomic weight work; he made use of the laws of isomorphism, specific heats, and combination of gases by volume, and carried out analyses and syntheses without number; his work on atomic weights extended to many elements, including metals, non-metals and rare earths. As a standard atomic weight, Berzelius took oxygen equal to 100. His first table of atomic weights appeared in 1818; a revised table, which took into consideration the newly discovered laws, was issued in 1826. Many of the determinations of Berzelius, calculated to oxygen equals 16, compare favorably with the results of recent investigators.

The next great investigator to devote his life to atomic weight research was Jean Servais Stas, whose first work on the atomic weight of carbon appeared in 1841. His work on silver, sodium, potassium, lithium, lead, chlorine, bromine, iodine, sulphur, nitro-

gen and oxygen is classic. Stas was exceedingly careful in all his work, yet was guilty of errors in manipulation, for instance, he would drop dry sodium chloride into silver nitrate solution, and yet expect to obtain a precipitate of pure silver chloride free from occluded or included sodium chloride. In his earlier work, he neglected the solubility of silver chloride in water. In his investigations, Stas referred the halogens to silver. The task was undertaken to test the truth of Prout's hypothesis that the atomic weights of all the elements are simple multiples of hydrogen equal to one. Stas decided that this hypothesis is without foundation.

Stas died in 1890; the work on atomic weights has been continued in Europe by such men as Guye and Gutbier and in America by Keiser, J. P. Cooke, Mallet, E. F. Smith, and T. W. Richards.

During recent years a conflict has waged among chemists concerning the standards for atomic weights. A few chemists led by Lothar Meyer have taken hydrogen equal to 1. The greater number of chemists have used oxygen equal to 16. Few of the elements form compounds with hydrogen and the ratio of an element A to hydrogen can usually be determined only by multiplying the ratio of A to a second element B , which most frequently is oxygen, by the ratio of B to hydrogen. Now the ratio of oxygen to hydrogen has been determined by various investigators and cannot be regarded as a fixed value. All the elements save fluorine and the members of the argon-helium group form oxides and hence allow a direct comparison between oxygen and the elements. Moreover if the ratio of an element to some element other than oxygen (say to silver or chlorine) be determined, the ratio of this second element to oxygen has been definitely determined. Oxygen equal to 16.00 has been accepted by the International Committee on Atomic Weights as the standard, and the column referred to hydrogen equal to 1 has been dropped from their reports since 1906.⁷ However the United States Pharmacopœia still retains hydrogen equal to 1.000 as the standard.⁸

A new method for the determination of atomic weights was introduced by Smith and Maas⁹ in a paper "Über das Atomgewicht von Molybdän." They heated a known weight of anhydrous sodium molybdate in a stream of hydrogen chloride gas,

weighed the residual sodium chloride and calculated the atomic weight of molybdenum. This work has been continued by E. F. Smith and his pupils at the University of Pennsylvania.

Hibbs¹⁰ passed hydrogen chloride gas over heated potassium nitrate, weighed the residual potassium chloride and obtained the atomic weight of nitrogen. Sodium nitrate was treated in the same way for the same purpose. Sodium pyroarsenate, treated in this way, gave a value for the atomic weight of arsenic.

Lenher¹¹ treated silver selenite with hydrogen chloride gas, weighed the silver chloride formed, reduced the latter in hydrogen, weighed the metallic silver and thus obtained two values for the atomic weight of selenium.

Ebaugh¹² treated silver orthoarsenate with hydrogen chloride gas, weighed the silver chloride and then reduced the latter to metallic silver, which was weighed. This gave two values for the atomic weight of arsenic. Two more values were obtained by passing hydrogen chloride gas and hydrogen bromide gas over lead orthoarsenate, and weighing the residual lead chloride and lead bromide.

Friend and Smith¹³ determined the atomic weight of antimony by treating potassium antimonyl tartrate with gaseous hydrogen chloride, and weighing the residual potassium chloride.

Smith and his pupils have devoted much time to the determination of the atomic weight of tungsten. In 1899 Hardin¹⁴ stated that "So far as known, there is no perfectly reliable method for the determination of this constant. The method of reduction and oxidation is probably more accurate than any of the other methods which have been employed. The results obtained by it vary about one unit, and even more in exceptional cases." The story of the determination of the atomic weight of this element is a tale of the gradual elimination of impurities. Smith and Pennington took precautions to remove molybdic acid from their tungstic acid.¹⁵ Schneider had noticed a very slight residue when purified tungstic acid was dissolved in aqueous potassium hydroxide, but neglected it. Taylor¹⁶ found that purified tungstic acid, when treated with aqueous sodium carbonate, gave a white flocculent residue, which turned reddish-brown after standing in contact with the sodium carbonate solution for several hours. Exner and Smith¹⁷ prepared ammonium paratungstate from wolframite of Lawrence County, South

Dakota. In the mother liquor they isolated ammonium vanadophosphotungstate.¹⁸ Hardin¹⁹ had proved that tungstic acid obtained by ignition of ammonium tungstate contains nitrogen. Wyman²⁰ had experienced great difficulty in obtaining complete solution of tungstic acid in ammonia. Exner and Smith now examined the insoluble residues of Wyman and found them to contain ammonia and chlorine. To eliminate these impurities from tungstic acid, dry ammonium tungstate was thrown into pure boiling nitric acid, to which a small quantity of pure hydrochloric acid was added from time to time, and was digested for several hours. The tungstic acid thus obtained was thoroughly washed, suspended in water and dissolved by means of ammonia gas, in order to obtain ammonium paratungstate. This salt was submitted to fractional crystallization, and a product was finally obtained which did not give a precipitate on standing over night with sodium carbonate solution. Therefore this salt was free from those impurities which the investigators had striven to eliminate. The pure ammonium paratungstate was treated in porcelain vessels with nitric acid and a little hydrochloric acid, evaporated to dryness and ignited in order to obtain tungstic acid, which was reduced to metallic tungsten by the method of Hardin.²¹ The tungsten metal was heated in chlorine gas to obtain tungsten hexachloride. A weighed quantity of the hexachloride was converted into the trioxide by means of water, aided by a very slight quantity of nitric acid. From the ratio of the trioxide and hexachloride, the atomic weight 184.04 was obtained for tungsten.

Hardin has applied electro-analysis in the determination of the atomic weights of mercury, silver and cadmium.²²

A paper on atomic weights would be incomplete without reference to the work of T. W. Richards of Harvard and his pupils. Their work, which is found chiefly in the *Proceedings of the American Academy of Arts and Sciences* covers the atomic weights of copper, barium, strontium, zinc, magnesium, nickel, cobalt, iron, uranium, calcium, caesium, potassium, sodium, iodine, chlorine, sulphur, arsenic, nitrogen, silver and chromium.

Richards and the Harvard school have worked chiefly on the halides of the metals, changing them to silver halide which is weighed. In connection with this work, the nephelometer was invented to measure the opalescence of silver chloride solu-

tions. A perfected form of nephelometer has been described by Richards and Wells.²³ Elaborate apparatus for fusing and bottling pure salts and metallic silver for atomic weight work had been devised by Richards and Parker.²⁴ "A Revision of the Atomic Weights of Sodium and Chlorine,"²⁵ by Richards and Wells, shows in detail the manner in which Richards and his pupils attack a problem of this kind.

We thus see that the masters of the science for over a century have devoted their best efforts to determining these constants of nature. With the introduction of new and more accurate methods of analysis and of new methods for the purification of reagents, the old rule of Berzelius, which calls for the use of pure reagents and a simple method of analysis, is found to give accurate and concordant results.

REFERENCES.

- ¹ Ostwald's *Klassiker der exakten Wissenschaften* Nr. 3, *Die Grundlagen der Atomtheorie*, Abhandlungen von J. Dalton, 1-20.
- ² Remsen: *Principles of Theoretical Chemistry*, Fifth Edition, 34.
- ³ Ostwald's *Klassiker der exakten Wissenschaften* Nr. 8, *Die Grundlagen der Molekulartheorie*, Abhandlungen von Avogadro und Ampère.
- ⁴ Wurtz: *Elements of Modern Chemistry*, Fifth American Edition by Greene and Keller, 47.
- ⁵ Kopp: *Berichte der deutschen chemischen Gesellschaft*, 1879, xii, 909.
- ⁶ Ostwald's *Klassiker der exakten Wissenschaften* Nr. 68, *Das natürliche System der chemischen Elemente*, Abhandlungen von Lothar Meyer und D. Mendelejeff.
- ⁷ Report of the International Committee on Atomic Weights, *Journal of the American Chemical Society*, 1906, xxviii, 1; 1907, xxix, 107; 1908, xxx, 1; 1909, xxxi, 1; 1910, xxxii, 1.
- ⁸ *Pharmacopœia of the United States of America*, Eighth Decennial Revision, 596.
- ⁹ Smith and Maas: *Zeitschrift für anorganische Chemie* 1893, v, 280.
- ¹⁰ Hibbs: *University of Pennsylvania Thesis* 1896.
- ¹¹ Lenher: *University of Pennsylvania Thesis* 1898.
- ¹² Ebaugh: *University of Pennsylvania Thesis* 1901, *Journal of the American Chemical Society*, 1902, xxiv, 489.
- ¹³ Friend and Smith: *Journal of the American Chemical Society*, 1901, xxiii, 502.
- ¹⁴ Hardin: *Journal of the American Chemical Society*, 1899, xxi, 1026.
- ¹⁵ Pennington and Smith: *Proceedings of the American Philosophical Society* 1894, xxxiii, 332.
- ¹⁶ Taylor: *University of Pennsylvania Thesis* 1901.
- ¹⁷ Smith and Exner: *Proceedings of the American Philosophical Society*, 1904, xliii, 123.

- ¹⁸ Smith and Exner: Journal of the American Chemical Society, 1902, xxiv, 573.
- ¹⁹ Hardin: Journal of the American Chemical Society, 1897, xix, 675.
- ²⁰ Wyman: University of Pennsylvania Thesis 1902.
- ²¹ Hardin: Journal of the American Chemical Society, 1897, xix, 667.
- ²² Hardin: University of Pennsylvania Thesis 1896.
- ²³ Richards and Wells: American Chemical Journal, 1904, xxxi, 235; Wells: American Chemical Journal, 1906, xxxv, 99.
- ²⁴ Richards and Parker: Proceedings of the American Academy of Arts and Sciences, 1896, xxxii, 59, 63.
- ²⁵ Richards and Wells: A Revision of the Atomic Weights of Sodium and Chlorine, The Carnegie Institution of Washington, Publication No. 28, 1905.

Advantages of Enriched Air-Blast. J. W. RICHARDS. (*Met. Chem. Eng.*, viii, 123.)—The author discusses the combustion temperature attained in a blast-furnace and the methods used to raise it, with the increased efficiency resultant. He states that if the air be enriched with 5 per cent. of oxygen, the temperature of combustion is increased 370° over that attained by un-enriched air. It is estimated that the capacity of the furnace would be increased one-third; and that the velocity of the gases would be decreased on account of the smaller volume of nitrogen. The average temperature of the furnace would be lower, thus decreasing the loss by radiation, and the escaping gases would be richer in combustibles and therefore better fuel gas. The fuel economy is estimated at about one-sixth.

Prevention of the Formation of Coal-dust. (*Engineering*, lxxxix, 678, 2317.)—The sprinkling of coal with water, to prevent dust explosions is not popular either with owners or colliers. It has to be frequently repeated, the atmosphere becomes damp, and the mine muddy, and it requires much labor. The Kruskopf process substitutes a paste for water. Coal which dried in 6 hours when sprinkled, remained damp 3000 hours when treated with this paste. Comparative experiments showed that a dynamite charge of 5 Gm. produced a coal-dust explosion, but when the coal was treated with paste twelve successive charges of 160 Gm. failed to produce an explosion.

IN MEMORIAM.

Washington Jones.

Washington Jones, the venerable third Vice-President of the Franklin Institute, passed away on 30th July, ult., in the eighty-eighth year of his age. He was the son of Thomas J. and Eliza (Ranstead) Jones, born in Philadelphia February 22, 1822, and educated in the common school of his native city. Entering the employ of Merrick & Agnew as an apprentice in the Southwark Foundry in 1838, Mr. Jones retained his connection with that noted establishment and its various offshoots throughout more than a half-century thereafter. From 1838 to 1844 he studied under private tutors to acquire a mastery of his calling, and succeeded so well as to be accorded the post of Chief draftsman of the Penn Marine Engine Works in 1849, advancing to that of Superintendent of the Port Richmond Iron Works in 1856, Asst. Superintendent of the Southwark Foundry from 1861 to 1866 and General Superintendent and Constructing Engineer of the Port Richmond Iron Works from 1866 to 1891.

From that time on, Mr. Jones gradually retired from the forefront of industrial activity, but only to widen the scope of his interests in the field wherein he had helped to accomplish the great advances of the past two generations. He was director of the American Dredging Co.; a member of the American Society of Civil Engineers; member and past president of the Engineers' Club of Philadelphia; member of the Society of Naval Architecture and Marine Engineers; member of the American Institute of Mining Engineers and the Philadelphia Association for the Relief of Disabled Firemen.

At the time of his death Mr. Jones was the oldest surviving member of the Franklin Institute, having joined on January 21, 1847, and became a life member in 1853. He was elected to the Board of Managers in January, 1859; for many years he was one of the curators of the Institute and since 1902 served as Vice-President. His attendance at the meetings of the Board continued with scarce an intermission to the beginning of this summer's recess, and now that he is gone, the well-known figure of this valiant veteran of the mechanic arts, with his wealth of shimmering white hair wreathing his genial and kindly countenance, will long be held in pleasant memory by his associates.



Washington Jones

FRANKLIN INSTITUTE

LIBRARY NOTES.

Purchases.

- LEHMANN, O.—"Molekularphysik," 2 vols.
HÜBL, A. VON.—"Three-color Photography."
ABRAHAM, M.—"Elektromagnetische Theorie der Strahlung."
AMSTUTZ, N. S.—"Hand-book of Photo-engraving."
SMITH, F.—"The Stone Ages in North Britain and Ireland."
CHURCH, I. P.—"Hydraulic Motors."
KAYSER, H.—"Handbuch der Spectroscopie." Band 5.
International Catalogue of Scientific Literature: Seventh annual issue,—
D. Chemistry. Eight annual issue,—A. Mathematics; B. Mechanics; G.
Mineralogy; J. Geography.
BRILLOUIN, M.—Leçons sur la viscosité des liquides et des gaz."
BOUASSE, H.—"Cours de physique." 6 vols.
Résumés des Brevets d'Invention déposés en France. Année 1901, Acétylène,
Automobilisme, Piles et Accumulateurs. 3 parts.

Gifts.

- Abhandlungen der Kaiserlichen Leopoldinisch-Carolinischen Deutschen
Akademie der Naturforscher. Band 90 and 91. Halle, 1909. (From
the Academy.)
Statistics of Railways in the United States. Twenty-first annual report of
the Inter-State Commerce Commission. Washington, 1909. (From the
Commission.)
Graphic Arts and Crafts Year-Book, 1910. Hamilton, Ohio. (From Mr.
Max Levy.)
Celestial Ejectamenta. By Henry Wilde. Oxford, 1910. (From the
Author.)
Philadelphia College of Physicians, Transactions, vol. 31. Philadelphia,
1909. (From the College.)
American Iron and Steel Association, Statistical Report. Philadelphia, 1910.
(From the Association.)
Massachusetts Board of Education, Seventy-third Report. Boston, 1910.
(From the Board.)
Yale University Astronomical Observatory, Transactions. Vol. 2, part 2.
New Haven, 1910. (From the Observatory.)
Metropolitan Sewerage Commission of New York, Report. New York,
1910. (From the Commission.)
American Society of Heating and Ventilating Engineers, Transactions.
Vol. 14. New York, 1908. (From the Society.)
Newton (Mass.) Public Documents. Newton, 1910. (From the City Clerk.)
Commonwealth of Australia, Official Year-Book, 1901-1909. Melbourne,
1910. (From the Commonwealth Statistician.)
Queensland Under-Secretary for Mines, Report. Brisbane, 1910. (From
the Secretary of Mines.)

PUBLICATIONS RECEIVED.

La Métallographie microscopique par Louis Révillon, Ingenieur des Arts et Manufactures. Encyclopedie Scientifique des Aide-Mémoire. 176 pages, illustrations, 12mo. Paris, Gauthier-Villars, n.d.

Notions élémentaires sur la probabilité des erreurs par Maurice d'Ocagne, Ingénieur en chef des ponts et chaussées, Professeur a l'École des ponts et chaussées. 26 pages, illustrations, 8vo. Paris, Gauthier-Villars, 1910.

Link-Belt Company. "Link-Belt" coal tipples, retarding conveyors, car hauls and coal washeries. Booklet No. 95, revised 1910. 42 pages, illustrations, 8vo. Phila., Link-Belt Co.

Solid Bitumens, their physical and chemical properties and chemical analysis, together with a treatise on the chemical technology of bituminous pavements. By S. F. Peckham, A.M. 324 pages, illustrations, 8vo. New York, Myron C. Clark Pub. Co., 1909.

Handbuch der Telephonie. Nach dem manuskripte des Dr. Victor Wietlisbach, weiland technischer direktor des Schweizer telephonwesens in Bern. Bearbeitet von Dr. Robert Weber, professor der Physik an der Akademie in Neuchatel. Zweite auflage bearbeitet von Ingenieur Johannes Zacharias. 468 pages, illustrations, 8vo. Wien, Hartleben, 1910.

Statistik der Knappschaftsvereine des preussischen Staates im Jahre 1908. Nach amtlichen Quellen bearbeitet. Sonderdruck aus der Zeitschrift für das Berg-, Hütten- und Salinenwesen im preussischen Staate, Jahrgang, 1909 (Band 57). 73 pages, quarto. Berlin, W. Ernst & Son, 1909.

Canada Department of Mines. Summary report of the mines branch for the calendar year ending December 31, 1909. 181 pages, illustrations, 8vo. Ottawa, King's Printer, 1910.

Link-Belt Company. General price-list and Catalogue No. 90. 400 pages, illustrations, 8vo. Chicago, 1910.

Metzograph Grained Screen (Wheeler's patent), its application to block-making, photolithography and photogravure. 18 pages, illustrations, 8vo. London, A. W. Penrose & Co.

Canada, Department of Mines, Mines Branch. Bulletin No. 2. Iron Ore Deposits of the Bristol Mine, Pontiac County, Que., Magnetometric Survey, etc. By E. Lindeman, M.E. Magnetic Concentration of Ores. By George C. Mackenzie, B.Sc. 15 pages, illustrations, maps, 8vo. Ottawa, Government Printing Bureau, 1910.

Carnegie Library of Pittsburg. Technical indexes and bibliographies appearing serially. Reprinted from the Monthly Bulletin, June 1910. 17 pages, 8vo. Pittsburg, Carnegie Library, 1910.

Second International Congress of Refrigeration, Vienna, Austria, October 9-12, 1910. Announcement, program of meetings, etc. Chicago, American Association of Refrigeration, 1910.

North Carolina Geological and Economic Survey. Bulletin No. 18. Bibliography of North Carolina Geology, Mineralogy and Geography with a list of maps. By Francis Baker Laney, Ph.D., Assistant Curator of Geology in the U. S. National Museum and Katharine Hill Wood. 428 pages, 8vo. Raleigh, State Printer, 1909.

Allen's Commercial Organic Analysis. A treatise on the properties, modes of assaying, and proximate analytical examination of the various organic chemicals and products employed in the arts, manufactures, medicine, etc. Vol. iii, Hydrocarbons, Bitumens, etc., 4th edition, entirely rewritten. Edited by W. A. Davis, B.Sc., A.C.G.I., and Samuel S. Sadtler, S.B. Philadelphia, P. Blakiston's Son and Co., 1910.

Kurze übersicht über sämtliche Legierungen. Von Dr. Ernst Jänecke, privatdozent an der technischen Hochschule in Hanover. 100 pages, illustrations, 8vo. Hanover, Dr. Max Jänecke, 1910.

University of Illinois Bulletin, vol. 7, No. 2. Chemical and biological survey of the waters of Illinois. Report for year ending December 31, 1908. Edward Bartow, director. Water survey series, No. 7. 204 pages, illustrations, 8vo. Urbana, University.

Engineering Record directory of manufacturers of and dealers in engineers' and contractors' machinery and supplies, 3rd edition, 131 pages, 16mo. New York, Engineering Record, 1910.

Illuminating Engineering Society. Transactions, March, 1910, vol. 5, No. 3. Easton, Society.

Comments on Professor Swain's article on floods and forests (in American Forestry, April, 1910). By Thomas P. Roberts, United States Engineer's Office, Pittsburg, Penna. 5 pages, 8vo. Reprinted from Monthly Weather Review, 1910, 38, 496-498.

Georgia Geological Survey, Bulletin No. 24. A second report on the public roads of Georgia. By S. W. McCallie, State Geologist. 37 pages, 8vo. Atlanta, State Printer, 1910.

Zoological Bulletin of the division of zoology of the Pennsylvania department of agriculture. Vol 7, Nos. 11 and 12. Subjects: Bee-keeping, nursery inspection report, index to volume 7. April and May 1910. H. A. Surface, M.S., Economic Entomologist, editor. Harrisburg, State Printer, 1910.

Anregungen zur Organisation industrieller Betriebe. Von Ingenieur Dr. Robert Grimshaw. Uebersetzung eines von demselben Verfasser vor dem Franklin Institut, Philadelphia, gehaltenen Vortrages. Nach "Organisation, Fachblatt für leitende Männer in Handel und Industrie" gedruckt. 46 pages, 16mo. Hanover, Dr. Max Jänecke, n. d.

BOOK NOTICES.

DER KONSTRUKTIONSTAHL UND SEINE MIKROSTRUKTUR. Von A. Hæinig, Ingenieur. 360 illustrations, 8vo. Berlin, M. Krayn, 1910. Price, in paper, 15 marks.

The author presents the fifth volume of the Technical Automobile Library under the above caption. She also gives in an appendix "The Micrographic Researches Upon the Structural Components of Quenched Steel"—the work of M. Breuil.

In the introduction this volume treats of allotropism; over-cooling and under-cooling; the practical taking of cooling curves; the crystallization of salt-water solutions; the laws of melting and freezing points; the eutectic; the diagram of Roberts-Austin; that of Roozeboom; and constructions of the phase rule.

In the second part under the head of "Considerations of Special Steels Chiefly for Automobile Manufacturing" a review is made of the ternary steels such as nickel steel, chrome steel, tungsten steel, and vanadium steel; the quaternary steels such as chrome-nickel steel, chrome-vanadium steel, and nickel-vanadium steel; and of the composition of special automobile steels of the trade together with their microstructure and classification.

The third part treats of "Practical Metallography" in which the instruments manufactured by various firms on the Continent, preparation of test specimens, development of structure of various means, such as etching with divers reagents, and combined polishing and etching, the preparation of photographs including the developing and fixing of plates, are elaborated.

The appendix contains a series of photographs showing the structure of steels of various carbon contents beginning with 1.80 per cent. carbon and continuing to wrought-iron. It also contains photomicrographs of cast-iron with about 4.25 per cent. carbon. These photomicrographs show the structures resulting after a great variety of treatments. They are interesting and well reproduced; but of doubtful value to the automobile engineer.

The data contained in this volume has been compiled from the publications of the Alloys Research Committee; the various papers of Leon Guillet; Osmond; Ed. Maurer; Breuil; Dr. Rudolph Ruer; Martens; Heyn; and P. Goerens; and such journals as *The Iron and Steel Institute*; *Revue De Metallurgie*; *Metallurgie*; *Stahl und Eisen*; and the trade catalogues of the various iron and steel manufacturers of Europe.

Like most German compilations, the work seems to have been completely and thoroughly done. The illustrations are excellent; and naturally those illustrating the Krupp products are the most numerous and prominent. Mention is made of some steels manufactured by the Bethlehem Steel Company; and reference is made to the paper of John A. Matthews read for the Franklin Institute, April, 1909. No further mention is made of American contributions to the knowledge of Automobile Steels, or of firms manufacturing Automobile Steels in America.

G. W. S.

CURRENT TOPICS

Transport Phenomena in Solutions of Coloring Matters. LEO VIGNON. (*Comptes rendus*, cl, 923.)—Experiments on the electrolysis of solutions of dyes have shown that transport phenomena are well marked with those substances which form colloidal solutions but are absent in the case of dyes forming true solutions.

Simple Apparatus for Determining Melting Points. THEODOR WEYL. (*Chem. Zeit.*, xxxiv, 488.)—A thermometer is slightly expanded just above the bulb. A glass ring loosely fitting the thermometer stem rests on the expansion; it carries glass hooks placed vertically in pairs which serve to hold the melting point tubes in position close to the bulb. This obviates the use of india rubber rings or platinum wire for attaching the tubes to the thermometer.

The Photo-chemical Decomposition of Silver Halides. A. P. H. TRAVELLI. (*Chem. Woekblad.*, vii, 404.)—Ostwald's law supports the theory that the decomposition of silver halides into silver and halogen is attended by the intermediate production of silver sub-halides, and is opposed to the view that colloidal silver is formed directly from silver halides. These substances have the power of forming photo-chemical sub-halides only when in the solid state and not in the liquid state, but silver halides in solution are reduced by chemical "developers" to sub-halides. The presence of alkaline halides or ammonia induces reduction to metallic silver. The chemical "developer" may be regarded as a special solvent for the silver halide, the polymeric form of which goes into solution as a complex anion. Of the sub-halides the green variety is most sensitive to light, the red least, while the blue occupies an intermediate position.

The Ionization of Various Gases by the β -rays of Actinium. R. D. KLEEMAN. (*Proc. Royal Socy.*, A., 83, 530.)—The relative ionizations produced by the β -rays of actinium and uranium respectively in air, hydrogen, ethyl ether, ethyl chloride, ethyl bromide and ethyl iodide are the same. The β -rays of actinium, being of much lower velocity than those of uranium, it follows that the relative atomic absorptions and ionization are independent of the velocity of the rays for atoms up to the atomic weight of iodine.

Radio-active Recoil. SIDNEY RUSS. (*Le Radium*, vii, 93.)—The decay curves of the recoil products collected on a disc suspended 7 cm. above the bottom of an exhausted glass tube, on which radium

emanation is kept condensed by liquid air, agree well with the view that the number of atoms of *radium-A* and of *radium-B* recoiled are equal, but that of *radium-C* only a relatively very small number of atoms are recoiled. Since the first two substances both result in α -ray changes, whilst the third results in a change in which no α -ray but only slow β -rays are expelled, this is as is to be expected.

Use and Abuse of the Ionic Theory. G. N. LEWIS. (*Science*, xxx, 1.)—A criticism of the ionic theory in which attention is called to the common error of applying laws and methods to concentrated solutions, which are of such a character as to be applicable only to highly dilute solutions; to the danger of deducing too much from the additive properties of salt solutions; to the abnormal behavior of hydrogen ions and hydroxyl ions in water with the analogous high velocity of methylate ions in methyl alcohol; and lastly to the complete breakdown of the law of mass-action when applied to strong electrolytes.

Action of Light on Dyes. KURT GEBHARD. (*Zeit. Angew. Chem.*, xxiii, 820.)—The author confirms the theory that the bleaching of dye solutions or of dyed tissues by light is due to the primary formation of a peroxide of the dye. The peroxide is best detected by acidified potassium iodide and starch, by alkaline potassium permanganate, or by diphenylamine and concentrated sulphuric acid; chromic, molybdic and titanous acids do not indicate the presence of a peroxide; this fact forms one argument of several against the theory of the primary formation of hydrogen peroxide. The most effective rays are those complementary to the color of the dye. Blue, violet and ultra-violet rays exert a decomposing action on the peroxide, or occasion a transference of the active oxygen to un-attacked molecules of the dye.

Corrosion of Metals. (*Eng. Record*, lxi, 26.)—The Institute of Metals, of Great Britain, has appointed a committee to investigate the corrosion of metals other than iron and steel. Many manufacturers and users of non-ferrous metals have experienced many troubles on account of the corrosion of these alloys, particularly in marine work and power plants on the sea-coast. The results of such corrosion are frequently of such a serious nature as to make the investigation by the Institute a matter for congratulation among engineers.

The Carbo Process for Open-Hearth Steel. (*Iron Age*, lxxxv, 26.)—This modification has been developed by Louis M. Atha, Newark, N. J. Its object is to reduce the percentage or entirely eliminate the use of pig iron. The essential feature of the process is the introduction of "Carbo" into the furnace; *i.e.*, oil-retort carbon. This carbon is pulverized. It is very hard and re-

mains in the charge while melting down for a much longer time than other carbon. It is therefore absorbed and not carried off by the vapors. In working the open-hearth furnace, limestone or other suitable flux is introduced, then the steel and iron scrap, then the pulverized carbon and on top of this the pig- or cast-iron. The whole is melted down and the product is a fine grade of steel. "Carbo" is about 90 per cent. pure carbon and is extremely slow burning. The lime charge can be reduced when carbo is used and it is said that the value of the lime saved will about pay for the carbo. This reduction in lime allows the heat to be worked a little faster, thus reducing the fuel cost per ton and increasing the weekly production of the furnace.

Iron Ore in Northern Ontario. (*The Iron Age*, lxxxv, 26.)—It is reported that iron ore deposits have been found at Grand Rapids, on the Mattagami River, which is a tributary of the Moose River. The ore deposits are about 60 miles south of Moose Factory, and about 100 miles north of the National Transcontinental Railway and from the Temis Kaming & Northern Ontario Railway. These deposits have been known for some time. They were discovered in 1875 by Dr. Robert Bell of the Canadian Geological Survey; and were again noticed in 1903 by a party making explorations for the Ontario Bureau of Mines. The Bureau's report for 1904 contains a description of the deposits, which are classed as of the limonite variety of ore. The ore body is very large and the metallic iron found is sometimes as much as 60 per cent., containing only about 0.08 per cent. of phosphorus. Parties who have staked claims are very optimistic both as to the quantity and quality of the ore, which they consider to be brown hematite.

The Last of the Lake Whalebacks. (*Iron Age*, lxxxv, 26.)—The whalebacks proved unsatisfactory in the lake ore-carrying trade, as their peculiar shape made it impossible to use modern unloading machinery. Out of seven boats belonging to the Great Lakes Engineering Works, Detroit, only four have been operated this season. It is said the owners will dispose of all of them. Many of the original whaleback fleet have been used in the coal trade or as oil barges on the Atlantic Coast.

Strength of Steel in I-beams. E. L. HANCOCK. (*Eng. Record*, lxii, 2.)—This paper was read before the American Society for testing materials. It gives curves for the variation of the elastic limit and for stress deformation, with micro-photographs of test pieces. The conclusions reached are: (1) The elastic limit varies considerably for material cut from different portions of the beam, both standard and Bethlehem, being lowest in root of web, higher in flange near root, and highest in web. This confirms the work

of Prof. Marburg. (2) The indications are that there is a considerable difference chemically in the material in different parts of the beam. (3) The appearance of the fractured pieces indicates a considerable variation in the density of the material throughout the beam, due probably to the work of rolling. The thin beams show material superior to that of the thick beams.

The Influence of Titanium on Segregation in Bessemer Rail-Steel. G. B. WATERHOUSE. (*Eng. Record*, lxii, 2.)—The tests were made on ingots of rail-steel and ingots of similar steel to which 0.25 per cent. of titanium had been added during the pouring. There was no trace of the titanium in the steel with which it was used, but there was a marked increase in the soundness of the steel on account of the concentration of the blow-holes in the pipe cavity. A great number of drillings were taken from the ingots and analyses showed the effect of the titanium was to reduce the segregation of the sulphur, phosphorus and carbon; the results of the silicon and manganese determinations were too erratic for presentation, but they did not show segregation.

Intrinsic Brightness of Stars. C. NORDMANN. (*Comptes rendus*, cl, 669.)—As an extension of the application of Planck's law an attempt is made to determine the intrinsic brightness of certain stars by estimating the wave-length of the maximum brightness of their spectra. A table of results is given, showing that the order of effective brilliancy is in agreement with that of temperature gradation.

Cementation of Silicon Steels. LOUIS GRENET. (*Comptes rendus*, cl, 921.)—Silicon steels which do not undergo cementation under ordinary conditions when heated in charcoal, readily do so when the operation is carried out with potassium ferrocyanide.

Rotary Engine. (*Iron Age*, lxxxv, 23.)—The Herrick Engine Co. has announced the invention of its rotary engine. Hitherto none of the rotary engines invented have been successfully operated for any reasonable length of time. In this case an important new principle has been discovered, that of balancing unequal lateral thrusts on the rotor shaft of any rotary engine having but a single blade, and some other defects have been overcome.

Specific Heat and Heat of Solidification of Pig-Iron. W. SCHMIDT. (*Metal*, vii, 164.)—Swedish pig-iron was fused in a carbon crucible and introduced into an ice calorimeter, the temperature being measured by a thermocouple. Experiments were made at 1375°, 1275°, 1175°, and 1130° C.; in the last case the metal was introduced into the calorimeter immediately after solidification. Analysis showed the carbon content to be about

4.3 per cent. which corresponds closely to the composition of the eutectic. The results show that the specific heat of iron between 1175° and 1275° C. is 0.3136 and between 1275° and 1375° C. is 0.3216. Assuming that at 1130° C. the specific heat of iron is 0.31, the heat of solidification of white pig-iron of the eutectic composition is 59 calories per gramme.

Heroult Electric Furnaces. (*Iron Age*, lxxxv, 23.)—The Rombacher Huettenwerke have installed two Heroult electric furnaces, which are to be followed by four more of 12 tons each. The Heroult furnaces installed at the Deutscher Kaiser Stahlwerke at Bruchhausen, Germany, have commenced refining steel, and the results both in quality of product and moderate cost of operation are reported to be more than satisfactory.

Extrusion of Metals in the Solid State. (*Iron Age*, lxxxv, 25.)—An article on the extrusion of those metals which can not be readily drawn, *e.g.*, zinc, aluminum, copper, etc., which will be found very interesting and of value.

Constitution of Portland Cement. CLIFFORD RICHARDSON. (*Eng. Record*, lxii, 3.)—A most interesting and instructive article that will well repay perusal. It is strange that the users of Portland Cement know so little of its composition, which is probably due to the fact that the later researches into this material have only been made public in scientific journals which are seldom brought to the notice of engineers.

A Mono-rail Line. (*Eng. Record*, lxii, 4.)—Such a line, 3 miles long, was recently completed in the Bronx, New York City. On the first regular trip, when carrying 100 passengers, the supporting structure failed and the passengers were badly shaken. The car is 50 feet long and $6\frac{1}{2}$ feet wide, with seats for 50 passengers. It runs on a single rail, and is supported above by guide rails, engaging wheels on top of the car. These guide rails carry the 550-volt direct current for operating.

Titanium in Making Steel Rails.—(*English Mining Journal*, lxxxviii 1066.)—The use of titanium in making Bessemer steel for rails is becoming general. The method is to use ferrotitanium which combines readily with steel and purifies and improves its physical properties. The alloy is employed as a flux for cleaning iron and steel at the moment of casting or pouring from the converter. Sulphur and phosphorus are not reduced, but titanium in combining with oxygen and nitrogen form oxide and nitride. Titanium removes impurities, forming a stable combination which passes into the flux. The principal function of the titanium alloy is to act as a flux and the cleansing effect results in increased

solidity and purity, which have an important influence on the mechanical structure of the steel, preventing breaking down under heavy rolling loads and reducing the wear due to abrasion, which are serious defects in ordinary Bessemer steels. Ferrotitanium contains 10 to 15 per cent. titanium, 5 to 7 per cent. carbon and less than 5 per cent. of other impurities, the remainder is pure electrolytic iron. In Bessemer steel manufacture 1 per cent. of crushed ferrotitanium is added to the ladle as the steel is poured from the converter.

Corrosion of Structural Steel. (*Eng. Record*, lxii, 5.)—In bridges and in buildings that are exposed to the action of various corrosive elements, the disintegration of steel is so rapid, or the cost of protection is so large, that there is great need of some satisfactory preventative treatment. The electrolytic theory of corrosion seems to be based on sound principles and it is to be hoped that the interest now felt on the subject will not be allowed to decrease. Concrete is generally considered to be a good protective coating.

The Trans-Andine Railroad Completed. (*Iron Age*, lxxxv, II.)—This is the first transcontinental railroad completed in South America. It reduces the time between Valparaiso and Buenos Aires to 29 hours; formerly the overland journey occupied a week, and the journey by water, through the Straits of Magellan, took from 10 to 14 days. The total distance is 880 miles. The principal difficulties were encountered in one stretch of 13 miles at a high altitude in the Cordilleras. In these 13 miles are 15 tunnels, some of them short, but the one under the Cumbre Pass is 2 miles long. Some of these tunnels are straight, but most are curved and some wind around in a corkscrew manner.

Emergency Electric Lights for Ships.—The steamship *Alabama* of the Goodrich Line, which runs between Chicago and Muskegon, Mich., has recently installed an interesting system of emergency electric lights which is furnished with current from a storage battery.

These lights have been installed to provide illumination in the corridors and on stairways in case of an accident to the generating apparatus, or, in case of the sinking of the vessel, lights would be available to aid passengers in making their escape even after the hull of the boat had sunk some distance in the water.

In order to provide illumination as long as possible in case the boat should sink, the battery has been placed at the highest point of one of the upper decks.

The storage battery in use is composed of 56 cells type ET "Chloride Accumulator" in glass jars, manufactured by The Electric Storage Battery Co., having a rated output of 4.5 amperes

for 8 hours. This battery will supply current for 10 hours on one charge for 25 4-candlepower 110-volt carbon lamps which are in use in this installation.

The battery is charged during the day, and at night after the generators stop running, the lights used on decks, in halls and stairways are supplied with current from the battery alone. This system provides a reliable source of lighting which is always available in case of accident.

Similar battery equipments installed on other boats for furnishing current for emergency electric lighting service are also extensively used for the operation of wireless telegraph apparatus.

A New Resistor Furnace. F. A. J. FITZGERALD. (*Met. and Chem. Eng.*, viii, 317.)—Experiments have been made in a zinc smelting works in Upper Silesia, Germany, with a 150 kilowatt furnace in which the charge in the crucible is heated by radiation from an electrical resistor. By building the furnace with double walls, bottom, and cover, and burning fuel in the space thus formed, so as to keep the temperature therein approximately the same as that of the working chamber, it is stated to be possible to almost completely prevent loss of electrically generated heat, and to expect very great economies, especially in large furnaces. Furnaces of this type have been run continuously for nearly two months, and they may be allowed to cool repeatedly without having to be repaired. They are suitable for many other metallurgical operations besides zinc smelting.

Brown Stain for Wood. Patented by C. BUNNENBURG, Germany.—A concentrated ammoniacal solution of cupric oxide is mixed with four times its weight of a 4 per cent. solution of potassium bichromate. This mixture is said to impart a grayish-brown color to oak similar to that of old wood.

Action of Hydrogen on Platinum and Nickel Wire. M. VON PIRANI and A. R. MEYER. (*Z. elektrochem.*, xvi, 444.)—When nickel and platinum are heated to a high temperature in a current of hydrogen they undergo a permanent change. The nickel shows an increase of electrical resistance, the platinum, a lowering of the melting point and reduced ductility. This is apparently not due to the occlusion of hydrogen, but to the absorption of carbon from small quantities of accidental organic impurities carried by the gas.

Colloidal Metals. C. SERONO. (*Arch. Farmacol. Sperim.*, ix, 152.)—If an electric current be passed through a five per cent. solution of purified gelatin, rendered conductive by the addition of 1 per cent. of sodium chloride or sulphate, a colloidal solution of the cathode metal is obtained in about 10 minutes in the vicinity of the anode. With a gold cathode, the colloidal solution contains 42

mgm. of the metal per litre, and with a silver cathode, 87 mgm. per litre. An iron cathode yields a solution of ferrous sulphate, small quantities of ferrous hydroxide, and colloidal, non-dialyzable iron. The colloidal solutions are stable, contain no submicroscopic particles, and remain sterile. When a porous earthenware diaphragm is used, no trace of colloidal metal is found in the cathode compartment. These colloidal solutions are suitable for medicinal purposes when diluted.

Composition of Lime-Sulphur Spray. H. V. TARTAR and C. E. BRADLEY. (*J. Ind. Eng. Chem.*, ii, 271.)—The lime-sulphur solution, obtained by boiling together slaked lime and sulphur, which is used for spraying trees as an insecticide and a fungicide, was investigated both as to its composition and as to the chemical changes which the spray undergoes when used. The authors find that the chief constituents are calcium tetrasulphide and pentasulphide, but that these compounds are so readily converted into the more stable disulphide, with liberation of sulphur, that this excess sulphur might almost be considered as being merely in physical solution. Small quantities of thiosulphate, and traces of sulphite and sulphate, are also present. Free calcium hydroxide, and the monosulphide and the hydrosulphide appear to be absent. When the solution is sprayed on trees, the carbonic acid in the air acts upon it and liberates hydrogen sulphide and sulphur, but only to a small extent. The deposition of sulphur is almost entirely due to oxidation on the one hand, and to the mere evaporation of the solution on the other.

Open-Hearth Furnaces. TERPITZ. (*Stahl und Eisen*, xxx, 1029.)—The author considers from his experience that the effects produced on the products of the open-hearth furnace usually attributed to an excess of hydrogen in the heating gases, are not due to the gas itself but to the superheating of the charge due to the excess. Nitrogen also is not believed to be injurious, since the appearances supposed to be due to this gas are really the effect of the treatment in the subsequent stages. It is only in most rare cases that sulphur is absorbed by the steel. The only gases that have any influence are those produced in the bath by the oxidation and reduction reactions; the slag protects the metal from the heating gases. The effect of hydrogen on the sides of the furnace is discussed, and its effect is attributed to its high calorific value.

Gases in Steel. P. HÉROULT. (*Mét. and Chem. Eng.*, viii, 332.)—In opposition to the view that the amount of gases occluded in steel depends on the opportunities presented to the metal of absorbing them in the process of manufacture, the author states that repeated experiments have shown that the quantities of gases liberated, on placing the metal in a vacuum chamber, are approximately

the same from steels made by the Bessemer, basic, and acid open-hearth, crucible and electric processes respectively. Blow-holes, except when due to faulty moulds, are considered to be the result of liberation of carbon monoxide by the reaction of carbon and ferrous oxide in the steel. When molten steel has partly solidified, the carbon and ferrous oxide become concentrated in the portion remaining liquid, the condition of equilibrium is disturbed, and carbon monoxide is evolved, the blow-hole thus produced being filled with this gas at a high temperature. On further cooling, the pressure in the holes is diminished, and nitrogen and hydrogen are drawn into the holes from the surrounding metal, in the same way as those gases are disengaged when a piece of the solid metal is placed in a vacuum chamber. In conclusion it is stated that the small quantity of gases which may be present in steel are not injurious or detrimental to the quality of the metal.

The Coefficient of Equivalence in Special Zinc Bronzes. L. GUILLET and L. RÈVILLON. (*Rev. Métal.*, vii, 429.)—It was found that when part of the tin was replaced by zinc, the metallographical estimation, based on the area of the δ -constituent, indicated a content of tin higher than that found by analysis. The coefficient of equivalence of zinc was then estimated, but was found to be less than 0.1, showing that the effect of the addition of zinc was quite small. Zinc does not act by replacing one of the elements in the alloy, but dissolves in the copper without sensibly modifying the solubility of tin in the copper. For quantities of zinc up to 30 per cent., the alloys have similar mechanical properties to the corresponding alloys free from zinc, except that the solid solution free from zinc is harder than that containing zinc.

Separating Complex Ores, or their Concentrates. W. M. MARTIN, England.—Mr. Martin has patented a process for this separation by the use of sodium nitrate. Complex lead-zinc ores or concentrates are crushed and well moistened with a solution of an oxidizing agent, such as sodium nitrate, and the mass heated to dull redness for a few minutes. The ore is then crushed and the constituents separated by ordinary water concentration. About 2 per cent. of sodium nitrate is necessary for a crude ore, and a correspondingly larger quantity for a concentrate or an equivalent quantity of dry sodium nitrate thoroughly incorporated with the ore may be substituted for the solution.

The Antiseptic Properties of Copper. A. SPRINGER and A. SPRINGER JUN. (*Chem. Zeit.*, xxxiv, 585.)—Milk, suspected of containing antiseptics, was found to contain small quantities of copper (about 4 mgm. per litre). Its presence is ascribed to the wearing off of the tin coating on the copper utensils, and to the brass fittings in the dairy. Milk containing copper is remarkable for retain-

ing its sweet odor even when quite curdled; finally when covered with mould, it has a nut-like aroma free from any putrefactive odor. Milk which became sour in 10–12 days, in sealed bottles in an ice chest, kept for 22–24 days if one part of copper was added to 250,000 of milk. The authors conclude that copper salts should be useful remedies in the intestines in cases of diseases characterized by increase of the number of putrefactive bacilli.

Quick-drying Ink. Patented by A. RUETER, France.—An addition is made to the ink of a neutral, volatile substance such as alcohol or a similar material, in the proportion of one part to five of the ink.

Zinc Oxychlorides. DRIOT. (*Comptes rendus*, cl, 1426.)—Two oxychlorides were obtained by the action of zinc oxide on zinc chloride solutions, viz., $\text{ZnCl}_2 \cdot 4\text{ZnO} \cdot 6\text{H}_2\text{O}$ and $\text{ZnCl}_2 \cdot \text{ZnO} \cdot 1.5\text{H}_2\text{O}$. The first is a white amorphous body which loses 5 molecules of H_2O at 200°C ., but the last molecule is only driven off at a high temperature together with hydrochloric acid and zinc chloride. The second oxychloride is a microscopically crystalline body, losing one molecule of water at 230°C . and the remainder at a very high temperature, along with hydrochloric acid. To prepare these bodies the precipitated zinc oxide must be left in contact with the zinc chloride solution for several months, removing the solid mass from time to time to pulverize it. They are dried by suction and then by pressing between porous plates and filter paper. With the exception of the first of these bodies, which had been previously discovered, no indications were obtained of the eight oxychlorides found by previous experimenters.

Action of Heat on Carbon Monoxide. A. GAUTIER. (*Comptes rendus*, cl, 1383.)—Carbon monoxide was circulated through a porcelain tube heated to temperature ranging from 820° to 1300°C . and having an inner tube of glass which was cooled by a rapid current of cold water. Small quantities of moisture and carbon dioxide were formed, possibly due to the hydrogen present in the CO to the extent of 0.21 per cent. No trace of carbon or other deposit was observed. The author concludes that, at a temperature of 1300°C . under ordinary pressure, in porcelain tubes and in the absence of organic matter and metals, carbon monoxide undergoes no appreciable dissociation, and no carbon is set free.

Purification of Argon and Nitrogen. F. FISCHER and O. HAEHNEL. (*Ber.*, xliii, 1435.)—To remove possible traces of air and nitrogen from argon it is passed over red hot calcium. The apparatus is practically the same as that used by the authors for preparing argon, except that there is no external connection to the air; and that, for the vessel containing calcium carbide, there is substituted an iron tube containing metallic calcium, which is heated

in a combustion furnace. The portions of the iron tube which project from the furnaces are water-jacketed, and the corks are surrounded by jackets filled with mercury, so as to preclude all possibility of the entrance of air. All the glass stop-cocks in the apparatus are also provided with mercury joints, both at their upper and lower extremities, as are also the stoppers of the gas-holders. The whole apparatus, except the gas-holder containing the argon, is exhausted by the Toepler pump, and the circulation is then set up by the automatic rise and fall of the mercury in the circulating pump, and continued as long as desired. The density of the purified argon was found to be 19.945. Nitrogen, circulated over heated metallic copper, had a density of 14.018. A bright glow was visible in the apparatus during the circulation of argon, but not with nitrogen.

Corrosion of Iron and Steel. PROF. E. HEYN. (*Iron Age*, lxxxvi, 2.)—Steel, wrought-iron and cast-iron do not show notable differences in the attack of rust in still water, but such differences do appear in flowing water. Cast-iron is then attacked more vigorously than wrought-iron or steel. This is offset by the fact that in flowing water steel is attacked in a very irregular manner, so that in the same sample certain spots are attacked but little, while other spots are much corroded. With cast-iron the attack is considerably more uniform. The degree of the attack by rust of steel and cast-iron is dependent upon the speed of flow of the water. With increasing speed of flow the attack increases at first to decline again when the maximum is passed. In a strongly agitated solution of salt, the differences in the degree of attack of steel, wrought-iron and cast-iron decrease.

Formaldehyde in Foods. G. PERRIER. (*Rev. Soc. hyg. alim.*, v, 804.)—The author points out that extremely minute quantities of formaldehyde can be detected in foods by modern methods. Many food products, like smoked meats, contain traces of it, absorbed from wood smoke. A strict interpretation of the law would prohibit the sale of these foods, which is obviously not intended by the law-makers. It would therefore be better, instead of absolutely prohibiting formaldehyde, to establish a maximum limit for it. Formaldehyde was detected in smoked sausage, ham, red herrings, etc.

New Process for Softening Calcareous Water. (*Rev. gen. mat. color.*, xiv, 98.)—This process, invented by Gaus, depends on the use of permutite, a double basic aluminum silicate, made by fusing kaolin, quartz, and sodium carbonate. It reduces the hardness of calcareous water to zero, and it can be recovered and converted into its original condition by the use of a suitable salt, so that it can be re-used indefinitely. An iron cylinder is used,

with a layer of sand top and bottom and a layer of permutite between. The thickness of the permutite layer is proportional to the speed of filtration and the hardness of the water. The regeneration of the permutite is effected by pumping through it a 15 to 20 per cent. solution of sodium chloride (salt). This process has been adopted by several German and French chemical factories.

Water Disinfection. (*Engineering News*, xlii, 309.)—The use of bleaching powder, or calcium hypochlorite, as a disinfectant is called the most interesting and important recent advance in water purification. Special attention is called to the use of calcium hypochlorite as an aid to filtration and to the growing tendency toward decreasing the burden on filters.

Lithographic Stones in Greece.—Deposits of these stones were found three or four miles from Pharsala, in Thessaly, comprising nearly 5000 acres. The quantity is estimated at 35,000,000 cubic feet; at one point the thickness of the layers of lithographic stone was 20 feet. The thickness of the flags is generally one-half to one and one-half inches, occasionally reaching two inches. A layer of red clay divides the flags. For the most part the stone is of the pearl-gray variety, but there is a small proportion of white stone, worth double the value of the pearl-gray stone. Pieces of three to six square feet area, without any defect, are quite common, while some reach the enormous size of 13 to 16 square feet.

Nickel Wire. (*Engineering News*.)—The use of nickel wire for electric furnaces is not preferred to platinum, although it is cheaper, because nickel becomes brittle when exposed to high temperature. Professor H. C. H. Carpenter found this brittleness was partly due to the gradual escape of the occluded gases. On the other hand, Prof. M. Le Blanc, of Leipzig, found nickel wire suitable in experiments in which the furnaces were heated to 1300° C., and Nernst mentioned, during a discussion in the Deutsche Bunsen Gesellschaft, that he wound his nickel wire on a copper tube (instead of clay or porcelain) and insulated the copper with asbestos and sodium silicate; while the wire itself was finally coated with a mixture of sodium silicate and soapstone.

Barium in Blast-Furnace Slag. R. H. SWEETSER. (*Iron Age*, lxxxv, 5.)—When the silica in a blast-furnace slag goes below 30 per cent. and the sum of silica and alumina is below 43 per cent. there is danger of a "lime-set" in the furnace, or at least some very low silicon iron, and the composition of the slag should be changed. Such slags are hard to manage and require too much coke per ton of pig-iron to be economical. But when such a slag is found to be easy running, and requires little coke per ton of pig, it requires further investigation. Such a condition existed in

a furnace making Bessemer iron, with a mixture that yielded 57.4 per cent. pig-iron and required only 714 pounds of limestone per ton of pig. The slag gradually dropped to 28.90 per cent. of silica, but the furnace worked smoothly. Evidently there was an unusual constituent in the slag. A full analysis gave:

	Per cent.		Per cent.
FeO	0.40	CaO	45.10
SiO ₂	29.15	MgO	5.10
Al ₂ O ₃	13.40	BaO	2.45
S	1.85		

Here was a slag with 52.65 per cent. of bases and only 42.65 per cent. of silica and alumina, yet very fluid, and "white hot" while running and did not slack when cold. It was concluded that the barium oxide was the cause of the lower melting temperature.

Prof. H. O. Hofman has published a chart showing the effects of BaO and MgO in slags formed in lead and copper furnaces, and probably their influence would be the same in iron blast-furnace slags as in slags of non-ferrous metals. Briefly he shows that MgO raises the temperature curve while BaO lowers it, and therefore BaO is a powerful flux, and promotes the slagging of MgO. A slag having a formation temperature of 1150° C., was lowered to 985° C. when three-fourths of the CaO was replaced by BaO, and even when all the CaO was removed the temperature rose only to 1010° C. BaO also lowers the melting points of other refractory oxides.

The First Steam-Turbine Locomotive. (*Iron Age*, lxxxv, II.)—The new type of steam-turbine electric locomotive, where a turbine of the impulse type is directly coupled to a direct-current variable-voltage dynamo, has been completed at the works of the North British Locomotive Co., Glasgow, Scotland. It is stated that the tests were very satisfactory and confirmed the theoretical claims of its designers.

Natural Zirconium Oxide. (*Berichte*, 1910, 43.)—Large quantities of natural zirconium dioxide are found in the Minas Geraes district of Brazil, and the material is cheaper than zircon (ZrSiO₄) which was until recently the main source of zirconium compounds. There are three qualities of the natural zirconium dioxide, namely (1) black, glassy, kidney-shaped pieces; (2) broken, stony fragments; and (3) pebbles. The glassy variety has an olive green or brownish surface and breaks under the hammer to wedge shaped pieces; between these a brownish-yellow powdery mass occurs which contains all the iron, and can be mechanically removed. After its removal the residue contains almost 98 per cent. of zirconium dioxide; the black color is probably due to titanium. Its specific gravity is 5.41.

Photographs of the Flight of Shot. F. NEESEN. (*Phys. Zeitschr.*, x, 968)—The great height which balloon artillery must be able to reach necessitates an extension of the range-tables, hence photographic reproductions of the flight of projectiles are of particular interest, although they give no information as to velocity. Two photographs are included in the paper, one showing the path of a smoke-producing projectile, the other showing the end of the flight of five luminous projectiles from a mountain gun, taken in twilight. This is much clearer than that of the smoke shot and the paths of several shot can be shown on the same plate.

The Chemistry of Steam Boilers. (*La Nature*, No. 1922.)—We have frequently warned our readers of the inconveniences and even of the dangers in the use of water heavily charged with lime salts in steam boilers. To prevent the presence of this excess of lime salts in the water used for steam boilers, their treatment with various salts has been recommended, such as sodium carbonate or sodium sulphate or with lime. Basch, a German author, states that when sodium carbonate is used, any excess of it is partially decomposed into sodium oxide and carbonic acid—this decomposition does not commence until the temperature exceeds 160° C. He has also shown that the reaction between sodium sulphate and the calcium carbonate in the water is reversible,—



and that therefore an equilibrium may be established between these substances, which prevents a complete purification of the water.

Steel Balls as Burnishers. (*Amer. Mach.*, xxxiii, 16.)—Any small metal parts can be quickly and effectually burnished by placing the work in a horizontal tumbling barrel, made of wood to avoid scratching the work, together with a large quantity of small steel balls, in bulk about twice that of the work to be burnished, together with a mild soap mixture, and then rotating the barrel. The time required for the work varies inversely to the quantity of balls and directly to the size of the balls. This process takes the place of buffing, both before and after plating. The balls range from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch. Their cost, in reasonable quantity, is about 30 cents per pound.

Ammonia from Nitrogen and Hydrogen. F. HABER. (*Zeit. Electrochem.*, 1910, xvi.)—At 200 atmospheres pressure, and in presence of suitable contact substances, nitrogen and hydrogen combine to form ammonia in sufficient quantity for practical processes. The reaction is incomplete and the ammonia must be removed as it is formed, which is done by a system of circulation of the gases at high pressure. The ammonia is condensed and removed either as gas or as anhydrous liquid, the uncombined gases continue to cir-

culate through the system. Osmium is the most active contact material, and as a fine powder, at 175 atmospheres pressure and a temperature of 550°C ., a yield of 8 volumes per cent. is obtained from the mixed gases. As osmium is scarce, uranium, containing a certain amount of carbide, or carbon, may be substituted. This is transformed to a very fine powder which absorbs nitrogen and exercises a powerful catalytic action on the gaseous mixture at a temperature below 500°C . The power necessary for compression and circulation of the reacting gases is very small.

Cotton Bleaching. E. JUSTIN MUELLER. (*Bulletin Soc. Ind. Mulhouse*, 1909, lxxix.)—In a comparison of the material turned out from a number of bleach works, the author concludes that the most important factor in the removal of the dressing or size is the duration of the lye-boil. Different methods of bleaching, properly carried out, yield practically equally good results. An acid-steep, in dilute sulphuric or hydrochloric acid, does not appear to be very efficacious. The most efficient and rapid agent for the destruction of the starch is diastofor.

Rendering Fibres Inflammable. A. CHAPLET. (*Rev. Gen. Mat. Col.*, 1910, xiv.)—This is effected by the fixation of insoluble magnesium-ammonium phosphate in the fibre. The materials are padded in a concentrated solution of a soluble phosphate, preferably the mono-calcium salt, and are then passed through an ammoniacal solution of magnesium chloride. Magnesium ammonium phosphate is thus precipitated on and in the fibre, and after rinsing in very dilute ammonia and drying, the material is practically non-inflammable. This property is only slightly affected by rubbing or washing.

Carbon Bisulphide. F. KOREF. (*Zeit. Anorg. Chem.*, 1910, lxvi.) Equilibrium in the formation of carbon bisulphide from solid carbon and gaseous sulphur has been studied at various temperatures between 800° and 1100°C ., and the equilibrium constants obtained, both by the formation and dissociation of the substance. In each case the gas concerned was passed at varying rates through a heated tube, and equilibrium was assumed to be reached when the constant remained unaltered at different rates. Carbon bisulphide is found to be an exothermic compound, its heat of formation being 12,500 calories. The negative heat of formation observed by previous workers using solid sulphur is probably due to the very large heat of vaporization of sulphur.

Action of Ozone on Carbon Monoxide. P. CLAUSMANN. (*Comptes rendus*, cl, 1332.)—Clean glass tubes were filled with a mixture of ozonized oxygen (200 mgm. ozone per litre) and carbon monoxide. These gases were prepared separately and well purified,

then mixed in the tubes, which were sealed and exposed to light, when the gases were dried, by means of phosphorus pentoxide, and mixed in equal volumes, 2.83 parts of carbon dioxide were formed per 100 parts of total oxygen in 8 days; under the same conditions, but in the dark, only 0.88 part of carbon dioxide was formed. With the gases not dried and exposed to the light 3.67 parts of carbon dioxide were formed in one day.

Liquid- and Gas-Tight Joints. C. S. BEDFORD and F. ATKINS. (*Jour. Soc. of Chem. Ind.*, xxix, 7.)—A composition that is claimed for making tight joints in the screw-cap stoppers of vessels for the storage of petroleum, benzol, etc., consists of gelatin 40 parts, glycerin 42 parts, pigment 2 parts, water 15 parts. The composition is made into sheets, or spread upon a suitable fabric, from which discs or gaskets may be cut for making the joints.



The JOURNAL OF THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

OCTOBER, 1910

No. 4

THE COMPARISON OF GALVANOMETERS AND A NEW TYPE OF FLAT-COIL GALVANOMETER.

BY

EDWIN F. NORTHRUP, Ph.D.

THE term, galvanometer, is applied to electrical instruments of protean form and uses. Any article upon the subject "galvanometers," to have moderate length, must be written from a restricted view-point, and deal with instruments of a specific type. In the following pages, we shall make a few general remarks upon galvanometer-design, and describe a basis upon which the merits of different galvanometers may be compared in certain of their prominent features. We shall then describe the form, qualities, and adaptability of a comparatively new type of moving-coil galvanometer which has not been fully or adequately described heretofore. We shall add a table giving comparisons between galvanometers of different kinds and by different makers.

We may state, at the outset, that "sensibility" is not the sole requisite of a good galvanometer. Nor will the solution of the general equation of motion of a movable system, possessed of a moment of inertia, a coefficient of torsion and a damping factor, give much aid in the design or in the selection of a good galvanometer. The goodness of a galvanometer is to be judged by its adaptability to the work assigned to it as well as by the performance of which it is capable. The problem of estimating

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

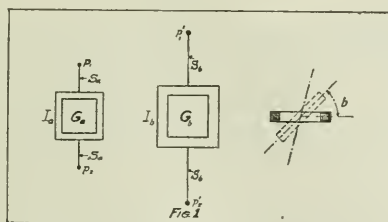
what, in a galvanometer, is essential to usefulness must be attacked by methods which experience in use and design teach, as well as by considerations of general principles. The designer must add to his experience, very clear conceptions of what the instrument will be called upon to do.

Every galvanometer design, by necessity, is a series of compromises. No one instrument can possess all the qualities, in full measure, desired. One's experience and judgment must guide to a proportionate selection of such diverse qualities as the following: sensibility, short period, accurate return to zero, tensile strength of suspension, freedom from easy disturbance by external influences, such as air currents, accurate balancing of the system to give stability against vibrations, proportionality in the deflections, strength and uniformity of the magnetic field, clearness and ease of reading the scale, freedom from magnetic impurities in the system of moving-coil instruments, variable or fixed damping to secure aperiodic return to zero, proper coil clearance for free motion and ease of adjustment, arrangements to facilitate transportation, freedom from parasitic currents resulting from internal thermo-electric forces, proper resistance of coil and suspensions, permanence of the galvanometer constant, small temperature coefficient, provisions for easy inspection of system and replacing of suspensions, high insulation where required, facility in mounting, adaptability to general classes of work as well as to a specific service, ease in construction, graceful appearance, and a construction which is moderate in cost. Besides such features in practical design, one must well understand the fundamental principles which underlie every galvanometer, if the best possibilities of the instrument are to be secured. As a beginning in design or in selecting an instrument for use, particular qualities, needed for a particular service, should have special attention. No universally serviceable instrument of this class, equally good for all kinds of work, ever was or ever will be constructed.

These preliminary remarks hint at the scope of the subject of galvanometer construction, and emphasize the necessity one is under, if he would pass judgment upon the merits of a galvanometer, to have first a clear conception of the use for which the instrument is intended. A galvanometer, admirably adapted to show the readings of a bolometer giving the energy distribu-

tion in the spectrum would make a poor lecture-room instrument for general demonstration purposes, nor, would it be suitable to put into students' hands for Wheatstone-bridge work.

A common basis for comparison of the respective worths of galvanometers of diverse pattern, in respect to the single quality which has been termed "the figure of merit" may be reached with a fair degree of satisfaction. A clear physical conception of this feature and what it means, will be a useful preliminary to any estimation of the worth of any current-measuring instrument. We may touch with advantage, therefore, upon this question, before describing the form, qualities, and uses of the special type of galvanometer, to describe which, is the leading object of this article.



Let Fig. 1, G_a and G_b represent, diagrammatically, two systems of any type of moving-coil galvanometer. Let these systems be held by suspensions, S_a and S_b , attached at points P_1 , P_2 , and P'_1 , and P'_2 .

Suppose the coil-winding of each is on a metal frame of such cross-section and conductivity that, when the system rotates in the magnetic field, its return to zero from a deflection is just aperiodic in virtue of the currents induced in the frame. To have this condition always fulfilled, one may conceive the conductivity of the frame to vary whenever the moment of inertia of the system, the torsion of the suspension, and the strength of the magnetic field are varied. This premised, let such a current pass through each system that it will be rotated through a standard angle, b , which may be made always the same by varying the strength of the current. Evidently the current which will be required to produce this deflection will depend upon many factors, chief among which are the strength and uniformity of the magnetic field, the torsional force of the

suspension, the length and number of turns in the coil, and the degree of freedom from magnetic impurities in the system.

The system, starting from rest, will require a certain time, T , after the current is applied, to complete a certain fractional part of its aperiodic deflection. To be definite, assume that the deflection is practically completed, when it has reached within one-twentieth per cent. of its final deflection. This time, T , will be, for all purposes of practical computation, the same as the time of a complete oscillation of the same system undamped. If I is the moment of inertia of any galvanometer system, then the square of its time of deflection, as above defined, or of a complete oscillation, if undamped, is proportional to this moment of inertia—or

$$T^2 \propto I.$$

Now so arrange matters that the same current through each of the two systems, G_a and G_b , will produce in each the standard angular deflection, b . Then the *sensibility*, S_m , of each system is the same and this sensibility will be inversely proportional to the current required to produce the deflection. If, however, the system G_a has a moment of inertia (I_a), and the system G_b a greater moment of inertia (I_b), then G_a will reach its standard deflection in a shorter time than G_b . The ratio will maintain that,

$$\frac{T_a^2}{T_b^2} = \frac{I_a}{I_b}.$$

By hypothesis, the sensibilities; that is, the currents required through each, to produce the standard deflection, are equal. Since, however, G_a deflects in a shorter time than G_b its suspension might be weakened until its time of deflection equals that of G_b . But with a weaker suspension it will take less current to produce the standard deflection. Hence, with equal times to make the standard deflection, the system G_a is more sensitive than the system G_b .

Conversely, to make G_b deflect the same amount in the same time as G_a , its suspension must be stiffened, and with a stiffer suspension, it will require more current than G_a for the standard deflection. In this respect it is a less sensitive galvanometer than G_a .

As it is always possible to vary within wide limits the tor-

sional force of a galvanometer suspension, a galvanometer, which is quick but not sensitive, can be made more sensitive at the expense of quickness by changing its suspension, and a galvanometer which is slow but sensitive, can be made quicker at the expense of sensibility. If we call S_m the sensibility of a particular galvanometer, and T its period, then the product, $S_m \frac{1}{T^2}$, cannot be increased by changes of the above character. We shall call this product proportional to the *useful sensibility* of any particular galvanometer and write

$$U \propto \frac{S_m}{T^2}. \quad (1)$$

By T we must understand the time of a complete oscillation, if the galvanometer is undamped, or the time it takes to reach within one-twentieth per cent. of its final deflection if it is damped magnetically to be just aperiodic.

For practical purposes of comparison of galvanometers, the time may be considered the same, for the instrument in either of these conditions.

While the sensibility, S_m , is inversely proportional to the current needed for the standard deflection, this current, if everything else remains the same, will be less as the number of turns in the coil is increased. Of two galvanometers, which are to be used on the same *constant-current* circuit, and which are alike in all features, except in respect to number of turns, that one which has the more turns will be the more sensitive. We can call, therefore, the sensibility of a galvanometer, for use on a constant-current circuit, a quantity which is proportional to its number of turns, and inversely proportional to the current required to produce a standard deflection. Or

$$S_m \propto \frac{n}{i}. \quad (2)$$

Hence, its useful sensibility is

$$U \propto \frac{n}{iT^2} \propto \frac{S_m}{T^2}. \quad (3)$$

To increase the number of turns we may proceed in either or both of two ways: the size of the insulated wire may be diminished and the same winding space be filled, or the wire

may be kept the same and the dimensions of the cross-section of the winding channel may be increased. By the first method the moment of inertia of the system remains nearly the same. It would remain exactly the same, if in altering the size of the wire no alteration were made in the density of the coil by changing the ratio of insulation to wire through a change of wire size. By the second method, the moment of inertia, and hence T^2 , will be changed unless the length of the turns are also diminished in a proper proportion. We have seen that U , the quantity which we have called the useful sensibility of a galvanometer, cannot be changed by changing the torsional force of its suspension, but that it may be changed by changing the coil winding. Thus, in changing n , if the moment of inertia only is changed, T^2 will be changed and U will be changed, because the period changes, but, if n is changed in such a manner as not to change the period, then U will change again, because S_m , the sensibility, changes. If n is changed in such a way as to vary both S_m and T^2 , U will still change unless the exceptional condition is met, that n so changes that $\frac{n}{T^2}$ remains constant. We conclude, by the above line of reasoning, that *useful sensibility* is a constant property of a particular galvanometer with a particular winding, but a quantity which varies when the coil windings are changed. But if we divide the useful sensibility by the number of turns in the coil and write

$$F \propto \frac{U}{n} \propto \frac{S_m}{n T^2} \propto \frac{1}{i T^2} \quad (4)$$

we obtain the new quantity, F , which has been designated the "figure of merit" of a galvanometer.

The figure of merit of a galvanometer, is a kind of "specific quantity" which attaches to every galvanometer. As the useful sensibility of a galvanometer cannot be improved by changing the torsional force of its suspension so also we cannot increase the figure of merit of a galvanometer by changing either its suspension or the turns in the winding space of its coil. A galvanometer with a certain "figure of merit" is potentially, so to speak, capable of having a certain chosen period with a certain accompanying sensibility and number of turns, or a

certain chosen sensibility with a certain accompanying period and number of turns, but to increase the figure of merit, changes must be made in the field-strength or in the proportioning of the galvanometer parts. As "figure of merit" attaches as a specific property to every galvanometer, it serves in a useful way to compare the intrinsic worths of various types of instruments. If, however, we wish to compare the figures of merit of different galvanometers, we cannot do so practically by using the expression above in its present form, because there is no easy way of counting the number of turns in the coils after the galvanometers are built. It is necessary, therefore, to find how the resistance of the coil is related to its number of turns, for this is a quantity easily measured. To do this, write

$$R = \frac{4l_1\rho n}{\pi W^2} \quad (5)$$

where l_1 = length of mean turn,

W = diameter of wire,

ρ = specific resistance of wire.

If S = cross-section of channel and

d = double thickness of wire insulation, then,

$$n = \frac{S}{(W+d)^2} = \frac{\pi S}{\pi W^2 + 2\pi Wd} \quad (6)$$

the term πd^2 being neglected, as being very small.

From (6) we derive $\pi W^2 = \frac{\pi(S-2Wnd)}{n}$, and putting this value of πW^2 in (5) we obtain,

$$R \propto \frac{n^2}{S-2Wnd} \quad (7)$$

Solving this quadratic and using the positive sign before the radical, we obtain,

$$n \propto \sqrt{RS + R^2W^2d^2} - RWd. \quad (8)$$

When this value of n replaces n in the expression (4) for F we have as the resulting expression, not involving n , for the figure of merit of a galvanometer,

$$F \propto \frac{S_m}{T^2[(RS + R^2W^2d^2)^{\frac{1}{2}} - RWd]} \quad (9)$$

Except in cases where galvanometers wound with coarse wire are compared with galvanometers wound with very fine wire, the thickness, d , of the insulation may be neglected. We may consider S constant and we have when we do this,

$$F \propto \frac{S_m}{T^2 \sqrt{R}} \propto \frac{U}{\sqrt{R}} \propto \frac{1}{iT^2}. \quad (10)$$

$\frac{S_m}{T^2 \sqrt{R}}$ is the usual expression for the figure of merit of any galvanometer. In comparing galvanometers by it, the supposition is made that thickness of insulation is neglected and that the galvanometers compared are wound with wire of the same *specific resistance*. The specification which we shall adopt to define S_m is as follows:

With the scale at 1000 scale-divisions from the mirror, of a mirror galvanometer, the sensibility, S_m , is the number of megohms which must be in the galvanometer circuit so that with an E.M.F. of one volt in the circuit, there will result a deflection of one scale division. With this understood, we can write:

$$F = \frac{S_m}{T^2 \sqrt{R}}. \quad (11)$$

A galvanometer would have, then, a unit figure of merit, if its time of a complete oscillation is one second, or which is practically the same thing, if its time of aperiodic return to zero within one-twentieth per cent. of its previous deflection is one second, and the resistance of its winding is one ohm, and when, with one megohm in series and one volt in circuit, its deflection, on a scale one thousand scale divisions from its mirror, is one division.

As this unit has received no name, we will call it, for convenience a *D'Arson*.

We can say, also in accord with the above definition of sensibility, that the sensibility is unity when one micro-ampere produces the standard deflection. Hence, if i_m = the micro-amperes in the galvanometer circuit,

$$S_m = \frac{1}{i_m}.$$

If E_m micro-volts are applied at the terminals of the galvanometer of resistance R , we have,

$$i_m = \frac{E_m}{R} \text{ or } S_m = \frac{R}{E_m}.$$

Putting this value of S_m in (11) gives:

$$F = \frac{\sqrt{R}}{E_m T^2}. \quad (12)$$

The relation (12) defines the figure of merit of a galvanometer in terms of its resistance, period, and the number of microvolts applied at its terminals to produce the standard deflection.

As an example of the use of relation (11) suppose we have a galvanometer with a complete period of 5 seconds, a coil resistance of 400 ohms, and which deflects one scale division with one volt acting through 500 megohms, then its figure of merit is,

$$F = \frac{500}{5^2 \sqrt{400}} = 1 \text{ D'Arson.}$$

If this galvanometer were given a longer period, by using a weaker suspension, its sensibility would be larger, but F would not be altered by this change. It is evident that the coil might be wound, using the same size wire, to a smaller resistance, but if this were done the mass of the coil would be less and hence T^2 would be smaller. Both of these changes would contribute to a greater figure of merit. On the other hand, a smaller resistance would mean a smaller number of turns which would reduce the sensibility and hence diminish the figure of merit. Thus it is always open to the designer, to so choose the winding and proportion the coil, and to so arrange the strength of the magnetic field and other factors that F shall be large. The success with which he does this determines in considerable measure the perfection of his design.

It must not be forgotten, however, that the number of D'Arsons possessed by a galvanometer is not necessarily a final measure of its fitness for actual service. It may possess faults of many kinds which more than offset a large figure of merit. Chief among such is zero shift, and magnetic impurities in

the system, which two, in fact, generally go together. There are also other common defects, as small coil clearance, inaccessibility of the parts, a poor optical system, an unproportional scale, a provoking tendency of the system to respond to small tremors, and a host of other minor defects which the user soon observes and condemns.

If it were not necessary to load a galvanometer system with a mirror, or a pointer for the purpose of reading the deflections, it would be possible by proper designing and by a great diminution in the size of the moving parts to realize an instrument which would possess an enormous figure of merit as compared with an ordinary moving coil galvanometer. This has in fact been done in the case of the Einthoven String Galvanometer, which has about 3000 times the number of D'Arsons of a good moving coil galvanometer using a mirror and scale. We are led thus to the general consideration of what are the possibilities of obtaining a great figure of merit for galvanometers of the deflection type.

In every galvanometer of this type we may consider the moment of inertia of its moving system as made up of two parts: One part is the moment of inertia which is contributed by the mirror, the pointer, or whatever device may be attached to the system which is required for reading the deflections of the instrument. We may make this reading device small but we cannot dispense with it altogether and preserve the instrument as a galvanometer of a type to which the name is ordinarily applied. Indeed there are many practical considerations which soon put a limitation upon a continual diminution of mass of these parts. The other part is the moment of inertia which belongs to the moving wire or magnets, which constitute the effective working element of the system. This part of the total moment of inertia can be modified at will by the designer with the object of making the figure of merit of the galvanometers large as possible. The question then arises, has the figure of merit a maximum value which the most skilful designing cannot exceed? If there were no "dead parts" attached to the system, for reading deflections, then, theoretically, a galvanometer could be given, by proper designing, an indefinitely great figure of merit. This realization is obtained practically in the Einthoven String Galvanometer. But as long as galvanometers

continue as instruments read with mirrors or pointers, there will be a theoretical maximum figure of merit which cannot be exceeded. This proposition may be supported as follows: Call I_t the moment of inertia of the entire moving system, I_s the moment of inertia of the portion of the system active in producing a turning movement, and I_r the moment of inertia of the "dead parts," *i.e.*, the mirror, or pointer which, from practical considerations is fixed in value, though chosen small as possible. In I_r must also be included the winding form, if there is one, and the stem or axis of the system. We shall now have:

$$I_t = I_s + I_r \propto T^2 \quad (13)$$

and expression (11) for the figure of merit becomes:

$$F \propto \frac{S_m}{(I_s + I_r) \sqrt{R}} \quad (14)$$

Assume the galvanometer of the moving coil type, and, in modifying the design of its system, let the coil resistance be maintained constant. Then:

$$S_m = f(I_s). \quad (15)$$

This means that the sensibility of the galvanometer will be some function of that part of the moment of inertia which is active in producing a turning moment. For, the resistance being kept constant, a change in the number of turns, and hence in the moment of inertia of the winding, will modify the sensibility. Then we have:

$$F \propto \frac{f(I_s)}{I_s + I_r}. \quad (16)$$

In this expression, as F is modified by modifying I_s while I_r as well as the resistance, is held constant, we arrive at a relation which must hold in order that F shall be a maximum. Thus:

$$\frac{dF}{dI_s} = \frac{(I_s + I_r) f'(I_s) - f(I_s)}{(I_s + I_r)^2}. \quad (16)$$

The right hand member of (16) equated to zero gives:

$$I_s = \frac{f(I_s) - I_r f'(I_s)}{f'(I_s)} = \frac{S_m - I_r \frac{dS_m}{dI_s}}{\frac{dS_m}{dI_s}}. \quad (17)$$

As an example of the application of (17) suppose the moving system to be a rectangular coil of square cross-section. Then, very nearly, I_s will be proportional to the cross-section of this coil. Now conceive the cross-section of the coil, modified in such a way that the number of turns, and hence the sensibility, S_m , will increase, while the resistance of the winding is kept the same. Then R remaining constant, S_m will be some function of I_s . To find this function, we can reason as follows: If the cross-section of the wire is increased a times without a change in the number of turns, the cross-section of the coil is increased a times, and hence the moment of inertia is increased a times. But this increase in the size of the wire reduces the resistance to $\frac{1}{a}$ of its former value. Hence, to bring back the resistance to its original value, and keep the same size wire, the number of turns must be increased a times. This will increase S_m a times and again increase the cross-section a times. Thus altogether I_s is increased a^2 times. Therefore, we have by making these changes:

$$S_m \propto f(I_s) \propto \sqrt{I_s}$$

and

$$\frac{dS_m}{dI_s} \propto \frac{1}{2\sqrt{I_s}}$$

and putting these values in the general relation (17) found above, gives:

$$I_s = I_r. \quad (18)$$

This result means, that when we have chosen the moment of inertia of the winding of a rectangular coil, equal to the moment of inertia of the "dead parts," mirror or pointer, the resistance of the coil remaining always the same, we have designed the proportions of the coil such, that the galvanometer, in this respect, has the greatest figure of merit which it is possible to give it.

Every consideration shows us that in starting out to design a galvanometer, of any type which is to have a large number of D'Arsons, one should begin by carefully considering the selection of the mirror, pointer, or other contrivance essential to reading the deflections, so that this contrivance may have the least possible moment of inertia; for it is the mass of these

“dead parts” which ultimately sets a limit to the maximum figure of merit obtainable. The dispensing of “reading parts” in the Einthoven String Galvanometer is the essential reason for its enormous number of D’Arsons. Similar considerations hold for oscillographs, wattmeters, pointer volt and ammeters and other deflection instruments in which a high figure of merit is desired.

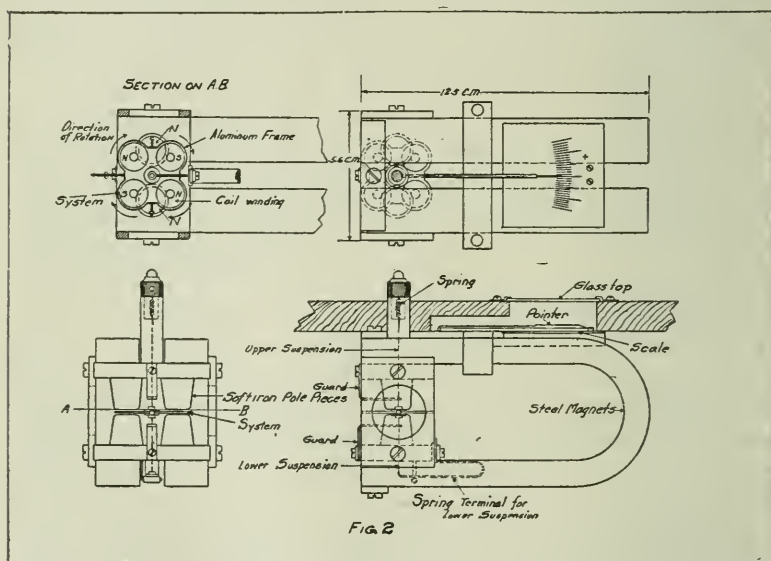
FLAT-COIL GALVANOMETERS.

The flat-coil galvanometer is a somewhat radical modification of the D’Arsonval type of moving-coil galvanometer. The modification was made by the writer to make the moving-coil instrument into a sensitive, substantial and portable galvanometer in which suspensions might replace the customary jewels. As will appear later, a suspended system may be arranged to withstand rougher handling than a system mounted in jewels, and there is the further marked advantage in a suspended instrument that there is nothing which corresponds to an initial pivot-friction. If very minute deflections of a pivot instrument are optically magnified, they will be found to be erratic and in no wise proportional to the forces acting. A suspended instrument, on the other hand, will deflect somewhat with the feeblest force and if its minute deflections are highly magnified by optical means, they will be found to be proportional to the deflecting force. This circumstance especially adapts a suspended instrument to zero measurements. Furthermore, the disk-like shape of the moving system lends itself in a portable instrument, with a suspended system, to a construction which requires a comparatively small height. Of several varieties of this type of instrument experimented with, the four-coil type has survived as being the best form and meeting in all respects the requirements demanded of it in a remarkably satisfactory manner.

Fig. 2 shows the construction of one type of this instrument, used as a pointer—portable instrument. The cut is made complete and explicit to save lengthy description.

It will be observed that when current energizes the four disk-like coils they all contribute to produce rotation in the same direction. A reversal of the direction of the current reverses the direction of rotation, the deflections, with equal current, being the same to either side of the zero.

At first sight this form of system might seem bad for giving a high figure of merit because so large a portion of the moving parts are far removed from the axis. While this is true, there are compensating advantages which practice shows makes the galvanometer very creditable in respect to figure of merit, while many features are secured which are of great practical worth. In the first place, as the galvanometer has no iron core there are only two air-gaps, one above and one below the coil, instead of four, as required by the D'Arsonval galvanometer with an iron core; in the second place *all* of the magnetic field is active



at all times in producing a turning moment, regardless of the angular position of the system. In the D'Arsonval type, a magnetic field must be provided for the system to deflect into. This is shown by Fig. 3.

Thus if the coil section C_1 occupies one-fifth of the air gap, or space in which the coil turns, then four-fifths of the magnetic lines are at all times idle. Magnets of sufficient strength and capacity must be supplied to furnish five times as many magnetic lines as are at any one moment used. The four-coil galvanometer has a large advantage in this respect.

Thirdly, the aluminum form in which the four coils are

held serves admirably as a magnetic damper. Further, if the instrument is to serve as a ballistic galvanometer, its moment of inertia can be made very great out of material which is active in producing a turning moment and for such service the construction is ideal.

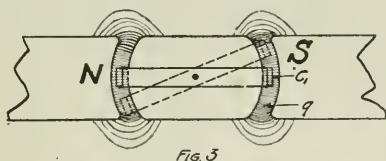


FIG. 3

The best proportioning of the system and coils to give specific results has received at the hands of the writer much thought and calculation. A few relations, which may have a general interest will now be given:

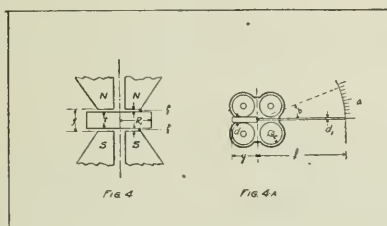


FIG. 4

FIG. 4A

Reference is to be made to Fig. 4 for the significance of many of the symbols used. Let W = the diameter of the wire with which each of the four coils is wound; let q = the double thickness of the insulation on this wire.

Then the expression for the *number of turns* in the four coils is:

$$N = \frac{4rt}{W^2 + 2Wq} \quad (a)$$

The expression for the *resistance* of the four coils is:

$$R = \frac{16r^2t\rho}{(W^2 + 2Wq)^2} \quad (b)$$

where ρ is the specific resistance of the wire.

The *torque* on the system due to a current i is:

$$t_1 \propto \frac{rti}{(t+p)(W^2 + 2Wq)} \quad (c)$$

If we give to the useful sensibility of the galvanometer, the definition of this quantity as explained on page 249, we assume that the system is supplied with a mirror, and that the scale is 1000 scale-divisions distant from the mirror. Then calling as above, S_m the sensibility, that is the number of scale-divisions which the galvanometer will deflect with one volt acting through one megohm, we have as the useful sensibility of the galvanometer:

$$U = \frac{S_m}{T^2}. \quad (d)$$

If the resistance of the windings of the four coils is R , we have for the figure of merit, of the galvanometer, expressed in D'Arsons,

$$F = \frac{U}{\sqrt{R}} = \frac{S_m}{T^2 \sqrt{R}}. \quad (e)$$

Since

$$\sqrt{R} = \frac{4r}{W^2 + 2Wq} \sqrt{\rho t}$$

$$F = \frac{S_m}{T^2} \frac{W^2 + 2Wq}{4r \sqrt{\rho t}}, \quad (f)$$

which is one expression for the figure of merit of the galvanometer. If the galvanometer has no "dead parts," that is no mirror or pointer, its moment of inertia will be proportional to the thickness of its system, or:

$$T^2 \propto I \propto t \text{ hence:}$$

$$F \propto \frac{S_m(W^2 + 2Wq)}{4r \sqrt{\rho t^3}}, \quad (g)$$

but its sensibility will be proportional to the number of turns with which it is wound, and if we keep the size of the wire the same, $S_m \propto n \propto t$, hence:

$$F \propto \frac{W^2 + 2Wq}{4r \sqrt{\rho t}}. \quad (h)$$

This relation shows that, using a wire of given size, the figure of merit will continually increase as the system is reduced in thickness and as the radius of the coils is reduced (it being assumed that the radius, R_1 , of the system as a whole diminishes in the same proportion as r). Thus, if the system did not have

to carry a mirror or a pointer, to gain in figure of merit it should be indefinitely reduced in size. Experiments confirm this conclusion, but in the case where the system must carry a pointer, we have to inquire what is the best length to give to the pointer (see Fig. 4).

Since in a given instrument any change which may be made in the length or mass of the pointer cannot effect the resistance of the coils or the sensibility, S_m , of the instrument, we can take the figure of merit as being inversely proportional to the square of the period. Or:

$$F \propto \frac{1}{T^2} \propto \frac{1}{I_t} \quad (i)$$

where I_t is the total moment of inertia of the system and the pointer. Let a be the length of the arc over which the end of the pointer moves, and l the length of the pointer. If b is the constant angular deflection, $a = bl$.

The quantity which we wish to have as great as possible is not a , or F , but the product of a and F , or

$$P = Fa = Flb \propto \frac{l}{T^2} \propto \frac{l}{I_t}, \quad (j)$$

is the quantity which, when the current is constant, is to be made a maximum. We see that this is so because, if we increase l for the sake of getting the end of the pointer to move over a longer arc, we do so at the expense of increased period, or smaller angular deflection in a given time, and hence, if the period is to be kept the same, the controlling force must be increased which would tend to diminish the arc. Or conversely, if l is diminished T would diminish and the angular deflection in a given time would increase, which would permit of using a weaker suspension thereby tending to increase the angular deflection and hence the arc. In other words, we want to make a galvanometer in which the end of its pointer shall move over as many scale divisions as possible while its useful sensibility or figure of merit is retained large as possible.

Now as before $I_t = I_s + I_r$, where I_s is the moment of inertia of the system and I_r is the moment of inertia of the pointer, together with that portion of the pointer y , which must be extended back of the axis for balancing.

It is easily shown, if $y = \frac{l}{4}$ in length, and if y and l are of uniform cross-section, and of respective diameters d and d_1 , that the end y balances the end l when $\frac{d}{d_1} = \frac{l}{y}$.

If s = cross-section of long end of this balanced pointer and σ = the density of the material of which it is made, it can be shown that the moment of inertia, of the entire pointer, proportioned as above, about its centre of gravity is,

$$I_r = \frac{5s\sigma l^3}{12}, \text{ hence, as } P \propto \frac{l}{I_s + I_r} \text{ we derive } P \propto \frac{l}{2.4I_s + \sigma s l^3} \quad (k)$$

$$\text{and,} \quad \frac{dp}{dl} = \frac{2.4I_s + \sigma s l^3 - 3\sigma s l^2 l}{(2.4I_s + \sigma s l^3)^2} \quad (l)$$

This becomes a maximum when:

$$l = \sqrt[3]{\frac{1.2 I_s}{\sigma s}} \quad (m)$$

In (m) we have a useful relation because the moment of inertia, I_s , of the system, can be obtained before the pointer is put on it, and the cross-section, S , and the density, σ , of the lightest material available for the pointer are also easily gotten. In a particular case the moving system of a four-coil galvanometer had a moment of inertia $I_s = 1.6$, the density of the material selected for the pointer was 3.3, and its cross-section was 0.0025 sq. cm. Hence, by the formula, the best length to make the pointer was found to be:

$$l = \sqrt[3]{\frac{1.2 \times 1.6}{3.3 \times 0.0025}} = 6.16 \text{ cm.}$$

In designing pointer instruments, such as galvanometers for use with thermocouples, etc., scant consideration is often given to this question: What is the most favorable length to give the pointer? but, that such consideration is important, must appear from the deductions given above. Accessory features, as magnets, suspensions, etc., are deserving of a few remarks.

For ease in shaping and in manufacture, cast-iron magnets are very suitable, and, if properly proportioned, they give a

field which is as strong as can be used with advantage in a galvanometer in which S_m is made large by the use of a weak suspension. There are always magnetic impurities in the coil system. The magnetic field in which the coil swings acts on these impurities, probably, in rough proportion to the square of the field strength. The result is, that the system takes on a polarity and tends, irrespective of the suspension, to set in a particular angular position. To show this strikingly, place the poles of a fairly strong permanent U-magnet near the poles of an ordinary wall form D'Arsonval galvanometer of about 400 megohms sensibility. It will generally show a permanent deflection of some 10 to 20 scale divisions as long as the U-magnet is held on.

The natural zero of the galvanometer is the position taken by the coil, which position is the resultant of the torsional force of the suspension, and the magnetic action of the field upon the magnetic impurities in the coil. When the field is weakened or changed in direction, the resultant controlling force changes, and hence a deflection results. In attempting an accurate measurement, by the Kelvin Double Bridge, of the resistance of a 3000 ampere standard low resistance, the writer recently used a Leeds & Northrup H-form Galvanometer in close proximity to one of the conductors carrying 1000 amperes. Whenever the circuit through the low resistance was closed the galvanometer deflected one scale division by the influence of the field external to the conductor. This deflection would have produced an error in measuring the resistance of one-tenth per cent., if it had not been discovered. The galvanometer was a very good one and the circumstance is related to show how precautions against exterior fields must be taken sometimes, even with moving-coil galvanometers. It also shows that little, if any improvement, can be obtained in weakly controlled galvanometers by using magnetic fields greater than can be obtained with cast-iron magnets. It may be mentioned here, also, that the chief cause of zero shift in sensitive D'Arsonval Galvanometers is due, not to the "set" in the suspension, but to a "magnetic set" which the coil takes when deflected in a strong field.

If a galvanometer is to have a quick period and a strong control, and be magnetically damped, then it is desirable to use a magnetic field of high intensity, such as can be secured only

by using soft Swedish iron pole-pieces and permanent steel magnets of the best quality.

Galvanometers which carry a pointer, or a mirror, and are intended for use on shipboard or for easy transportation and setting down without levelling, must be suspended between upper and lower suspensions, which are taut. Guards, which limit the movement of the system in all directions, together with a spiral spring in both upper and lower suspension, will effectually prevent the suspensions breaking, even when the galvanometer is subjected to severe jars.

It is desirable, however, to make the tensile strength of the suspensions great without undue increase in their torsional moment. The tension on the suspensions may then be made considerable and it becomes easy to accurately balance the system. This accurate balancing is essential to a steady zero and to make the system free from vibrations. A system, held between two taut suspensions, which is slightly unbalanced about its axis of rotation, is much more influenced by tremors than one which is carefully balanced.

The tensile strength of the suspension can be increased greatly without an increase in its torsional moment by making it of a number of round wires laid together in a cable, instead of a single wire. Thus:

Let n = number of wires laid together,

Let d = diameter of a single wire.

Then the torsion of one wire is, $t \propto d^4 \propto S^2$, where S is the cross-section of one wire. The total torsion of the n wires is:

$$T \propto d^4 n \propto nS^2.$$

If these n wires were to be combined into one, the tensile strength would remain the same, but the torsion would now be:

$$T_s \propto (nS)^2.$$

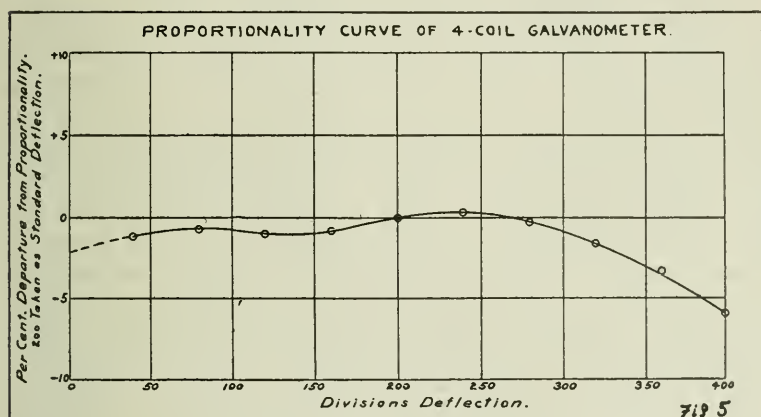
Hence,

$$\frac{T}{T_s} = \frac{nS^2}{n^2S^2} = \frac{1}{n}. \quad (n)$$

This conclusion, that with equal tensile strength, the moment of torsion decreases with the number of strands into which a given cross-section of wire is subdivided, has great practical value. It is much employed in galvanometer constructions

where the galvanometers are to be made portable. Contrary to expectation, there is no slipping of one strand over the other in a manner to develop friction and uncertain return to zero. The same method has been applied by the writer, with much success, to supporting heavy systems upon a cable made up of very fine quartz fibres. Its more extended application is recommended.

The four-coil type galvanometer here described is admirably suited to a differential instrument, especially for use in temperature measurements with resistance thermometers. Its applications to this service have been pointed out by the writer in a former publication.¹



When used as a deflection galvanometer, its deflections are not as proportional to the current flowing as might be desired. Fig. 5 is a curve which gives the average performance of the instrument in this respect.

The instrument has not been used with a mirror and fine suspensions for high sensibility work, but as it has been given a figure of merit of over 0.6 D'Arsons, it ought to serve well in this capacity.

In the present paper the discussion has been chiefly confined to galvanometers intended for use on constant or nearly constant current circuits. When galvanometers are designed for use with

¹ "Cooling Curves and a New Type of Apparatus for their Automatic Registration." Proc. of the Amer. Elec. Chem. Soc., May 7, 1909.

thermocouples and for reading millivolt or microvolt drops over low resistances, many points of design, and considerations regarding the galvanometer resistance, damping, etc., should receive attention; but the limits of this article will not permit a discussion of this phase of the subject. When dealing with galvanometers for use on constant potential circuits, it is preferable to use, as the expression for the figure of merit, the relation (12) given above. In this expression when $E_m = 1$ microvolt, $T = 1$ second, and $R = 1$ ohm; the figure of merit is unity, and then we might call the unit, a *microvolt D'Arson*.

We have collected together in a table the essential characteristics of sixteen different well known types of galvanometers for which see Table I.

Number 16 (Table I) is a galvanometer of the D'Arsonval type made by The Leeds & Northrup Company, which has the very high figure of merit of 2.80 D'Arsons. Its megohm sensibility, however, is but 121.8. Theoretically, a very fine suspension could be used until its sensibility should reach that of No. 13 which is 1750 megohms. Practically, however, this would not be feasible, because the suspension would be finer than any wire on the market except Wollaston wire. But were such a fine suspension used, the more serious difficulty would arise, that the coil would then be influenced to a relatively great degree by traces of magnetic matter in the coil. This would produce a large zero shift on reversed deflections. Thus, for high sensibility work, as in cable testing, where the longer period is not too serious a disadvantage, galvanometer No. 13 would be a much better instrument to use, although its figure of merit is but 11.4 per cent. of that of No. 16.

In respect to Table I the following remarks may be added. For the Einthoven String Galvanometer (No. 1) the resistance of the string was reduced to its copper equivalent, and a magnification of 100 was taken as the equivalent of a scale at 1000 scale divisions from a mirror.

The data for No. 2 was taken from Siemens & Halske's reprint No. 30, and the data for No. 4 was taken from an article by Dr. H. Sack in the same reprint. The data for No. 5 is from the Cambridge Instrument Co.'s catalogue. The data for No. 16, is based on the average of five instruments made by The Leeds & Northrup Company in August, 1910.

TABLE I.

No.	Type of instrument	Method of reading	Critical resistance for damping	Instrument resistance R	Megohm sensitivity S_m	Complete period T	Figure of merit
							$F = \frac{S_m}{\sqrt{RT^2}}$ in D Atsons
*1	Einhoven String	Microscope, 100 Fold Magnification	Aperiodic	287	5.2	0.01	3000.00
*2	Dubois Rubens, Iron-clad Moving, Magnet	Mirror	Aperiodic	290	12200.0	6.0	20.00
3	Siemens & Halske, High Sensibility	Mirror	120.	200	2500.0	12.0	1.24
*4	Siemens & Halske, High Sensibility	Mirror		290	1220.0	6.0	2.00
*5	Ayrton-Mather	Mirror	Undamped	20	52.6	3.5	0.96
6	R. W. Paul, Single Pivot Milli-Volt-meter	Pointer	25	50	21.4	3.0	0.33
7	Weston, Voltmeter	Pointer	Aperiodic	75	0.25	0.5	0.115
8	Weston, Portable Galv.	Pointer	3000	280	13.8	1.5	0.37
9	L. & N., Type P	Mirror	140	124	85.0	8.5	0.10
10	L. & N., Marine Type	Mirror	Aperiodic	1660	21.4	2.0	0.131
11	L. & N., No. 2300 Standard Four Coil	Pointer	300	300	15.54	2.5	0.14
12	L. & N., Type H	Mirror	Aperiodic	544	295.0	7.0	0.26
13	L. & N., No. 2280 Wide Coil	Mirror	Aperiodic	1420	1750.0	12.0	0.32
14	L. & N., Steel Magnet	Pointer	500,	230	8.8	1.3	0.344
15	L. & N., Special Small Four Coil	Mirror	500	85	6.4	1.0	0.695
16	L. & N., No. 2280 Narrow Coil	Mirror	200	180	121.8	1.8	2.80

* Data not obtained by author.

The Weston Voltmeter (No. 7) shows a figure of merit of 0.115 D'Arson. In considering the meaning of this low figure, it must be remembered that a light system has to carry a pointer which must be heavy enough to be perfectly rigid. The same system, fitted with a mirror would show a much higher figure of merit. The design of this instrument, as every one knows, is most scientifically worked out, and the fact that its figure of merit is low simply shows that one must exercise great caution against estimating the real worth of an instrument by this feature alone.

Philadelphia, Pa., August 16, 1910.

Polar Flattening of Jupiter's First Satellite. J. C. SOLA. (*Comptes rendus*, cl, 1224.)—Observed with powers of 550 to 750 on the 38 cm. Mailhat equatorial at the Fabra Observatory, the satellite Io presents a conspicuous flattening which is probably greater than that of any other known body in the solar system. From the measurements it appears that the equatorial plane of Io coincides with the plane of its orbit. The flattening was approximately determined as about 1 : 4.

Blast-Furnace Capacity in the United States. (*Iron Age*, lxxxvi, 8.)—From Nov. 1, 1907 to June 30, 1910, 35 blast-furnaces with a total annual capacity of 4,468,000 gross-tons were completed, and 12 furnaces, with a capacity of 287,000 tons dismantled. This shows a net increase in capacity of 4,181,000 tons. The impetus in this direction was, however, not exhausted for at that time 16 more furnaces, with a total annual capacity of 2,083,500 tons were in course of erection. The approximate capacity at the end of 1911 is placed at 40,228,000 tons. The highest level of consumption of pig-iron ever attained in the United States was during the latter part of 1909 and early in 1910, when it reached a level of 31,500,000 tons a year. This indicates to pig-iron consumers a comfortable margin of pig-iron capacity to meet the requirements of expanding trade.

Exportation of Agricultural Machinery. (*Iron Age*, lxxxvi, 8.)—During the fiscal year ending June 30, 1910, nearly 30 million dollars worth of machinery was exported, chiefly to Russia and Argentina. The competition is keen in Russia as Germany sold about \$8,000,000 worth of farm machinery in that country, and England \$5,000,000 worth. The value of the American machinery sent there is estimated at about \$7,000,000.

FUZE-POWDER.

BY

COL. ANTON DOLLECZEK,

Former Director of the K. u. K. Powder Factory at Stein.

[Translated from the Zeit. für das Gesamte Schiess- und Sprengstoffwesen, v, 13, 14. By W. J. Williams, F.I.C.]

SINCE the idea first originated of delaying the explosion of a shell for a certain time after it had left the gun-muzzle, special powder compositions have been sought which would burn for a given time. This space of time is regulated according to the duration of the flight of the shell, and at its completion the bursting charge is ignited by the flash of the fuze. These powder compositions are compressed into convenient bulks, either in the form of columns (fuze-tubes), or of flat rings, or of spirals.

For this purpose the fuze may be lighted at a given point and ignite the charge at the end, as is generally done in ring fuzes; or it may be lighted at the beginning and be so regulated, according to the estimated duration of the flight, that the shell is exploded at the end. This regulation of the period of burning may be effected by cutting off the train, piercing it, or by pinching it in, or by its abstraction. This method was generally used in the earlier column trains and fuze-tubes. Combinations of the two methods are sometimes though seldom used; and quite recently the original method has been reverted to, of compounding different slow-burning, mealed fuze-powders for different shells, when there is a large variation in their periods of flight; and naturally in such cases the early methods are practised.

The use of a special, compressed, mealed fuze powder dates far back, notwithstanding that at that time the knowledge of ballistics and the efficiency of the artillery was very modest. In the famous book, "Vollkommene Buchsen-meister Kunst, etc." by the Royal Polish Lieutenant Master of Ordnance, Kazimier Siemenowics, published in 1672, in Latin, four different slow-burning compositions for fuzes were mentioned, *e.g.*:

No. 1. One part mealed powder, 1 part potassium nitrate, 1 part sulphur.

No. 2. Three parts mealed powder, 2 parts potassium nitrate, 1 part sulphur.

No. 3. Four parts mealed powder, 3 parts potassium nitrate, 2 parts sulphur.

No. 4. Four parts mealed powder, 4 parts potassium nitrate, 1 part sulphur, and also 3 parts of antimony.

The well-known book "*Artilleriæ Regentior Praxis*" by the K. u. K. Captain of Artillery, Michael Miethen, printed in 1682, also gives four fuze compositions:

No. 1. Three parts mealed powder, 2 parts potassium nitrate, 1 part sulphur.

No. 2. Four parts mealed powder, 2 parts potassium nitrate, 1 part sulphur.

No. 3. Six parts mealed powder, $3\frac{1}{2}$ parts potassium nitrate, $2\frac{1}{2}$ parts sulphur.

No. 4. Eight parts mealed powder, 4 parts potassium nitrate, 2 parts sulphur.

These four fuze-powder compositions, with some slight changes in the proportions, remained unaltered in Austria through the whole of the eighteenth and the first half of the nineteenth century, about which time very finely pulverized brick-dust was added to retard the time of burning; and two new fuze compositions were first adopted in the new edition of the "*K. u. K. Feuerwerks-meisterei*" (treatise on pyrotechny):

No. 1. Seventy-five parts potassium nitrate, $19\frac{3}{4}$ parts sulphur, $5\frac{1}{4}$ parts charcoal.

No. 2. Seventy-three and a half parts potassium nitrate, $22\frac{1}{4}$ parts sulphur, $4\frac{1}{4}$ parts charcoal.

A fuze-column 4 Viennese inches (10 cm.) long of No. 1 has a mean burning time of 22 seconds, and No. 2 of 30 seconds.

The regulations of the Prussian Artillery of the year 1860 show 8 different fuze compositions, which consist of mealed powder with various additions of potassium nitrate and sulphur.

Major Shrapnel, an Englishman (the reconstructor of the old device of grenades,—shrapnel,—which contained balls as well as a bursting charge and which are named after him), used fuzes of equal length but of different duration of burning; and the gun-commander of the Austrian Gun-cotton Artillery M.

1863, actually carried in his fuze-pouch 18 copper fuze-tubes, of equal length, but of different ranges, varying from one another by 100 paces, which were simply set in the fuze-seat of the shell before firing. These were painted in conspicuous colors for easy discrimination.

It is evident then that all the earlier shells prepared in the traditional way, had fuzes in columnar form (fuze-tubes), and a composition was used with a sectional burning period of about 20 seconds to 10 cm. of composition; since the time of flight, especially of howitzers and mortars, was comparatively long on account of the low initial velocity.

However, with the advent of rifled cannon and the more rational construction of shells and of powder, as the initial velocity increased and the range lengthened correspondingly, this composition was no longer satisfactory for shells loaded with small balls and intended to explode in the air (now generally called shrapnel). Wherefore, an especial percussion apparatus was brought into use for the ignition of the fuze, since the systems of breech-loading with the development of pressure on the shell excluded the ignition of the fuze by the powder charge. At this time black powder in the mealed form was generally used, without consideration as to whether the mealed powder consisted of crushed powder grains, or was compounded in special proportions.

The Austrian and Prussian shrapnel column fuzes for the Wahrendorf artillery system, consist of copper fuze-tubes rammed full of mealed powder paste; and at first were drilled out from the lower end to the requisite length for the purpose of timing them, but later were perforated by a fuze-punch at the distance corresponding to the time of flight.

Bormann was the first to use the horizontal position, *i.e.* perpendicular to the axis of the shell, for the fuze composition (mealed powder was still used), and this method of locating the fuze has become more or less the basis of all modern fuze construction. This—to designate it more simply—horizontal fuze is in a special disc-form, and it may be turned around the axis of the shell, to coincide with a piercer or pin on the fuze. An empirical scale is marked on the edge of the fuze-disc. If the beginning of the powder train in the fuze-disc is set so that it is marked with an O, or else with, for example, +, K. A., etc., or

the percussion-fuze chamber is directly connected by the fuze with the bursting charge of the shell, then the shell explodes more or less immediately after leaving the muzzle (action of canister shot). On the other hand, the greater the distance of the ignition point of the fuze is from where it burns through to the bursting charge, the longer the shrapnel flies through the air before it explodes. If the end of the fuze-ring (which is separated by a little bridge of metal from the beginning) is brought to rest over the specified orifice, the flight of the shrapnel has then reached its maximum. More or less, all time fuzes are constructed on this principle. In case the time fuze, for any reason whatever, does not explode the shell in the air, or when it is purposely cut out (as for example in practice), another contrivance is put in operation, which causes an explosion of the fuze by direct impact and thereby of the shell too, on reaching the target. Fuzes which combine the percussion function with the time function are called "double fuzes" and are now general.

As long as a shrapnel range of 2000 to 3000 paces was satisfactory, ordinary powder sufficed for the fuze-ring. But soon higher demands were made both for accuracy and effect. The original intervals of the fuze-ring, which were about one second, were narrowed down to half a second and an eighth of a second; and definite explosion intervals and explosion heights were striven for (so the ordinates of the points of explosion might be termed in relation to the lineal distance of the target) and the uniformity of the combustion of the powder train extended—termed "Fuse-slowness" (literally "spreading").

The powder maker, of course, is only interested in the fuze-slowness, and it was considered, in Austria at any rate, that grain powder is preferable to the mealed powder, favored up to this time. This assumption has much in its favor, since as a rule the mealed powder is not so thoroughly incorporated, if it is not made from grain-powder; and, moreover, experience teaches that the uniformity in burning of the powder increases with the size of the grains, though within narrow limits and within small periods of time.

Table I shows the results of experiments made in the K. u. K. Powder Factory at Stein, carried out with spherical, slightly graphited powder, of the composition potassium nitrate 75 per

cent., sulphur 10 per cent., and 15 per cent. of alder-wood charcoal, containing about 74 per cent. of carbon.

By the "size of grains" is meant the mesh of the upper and lower sieves.

The time of combustion is the mean of 10 fuzes in a double fuze, where both discs together are 21.1 cm. long with a diameter of 2.5 to 3.0 mm. and a depth of 4.0 mm.

As the size of the grains increases from 0.20 mm. up, the time of combustion increases from about one-half to one second, and soon becomes constant, whilst the variation in burning remains practically uniform. The density decreases as the size of the grain increases, and it might be assumed that the greater the density the less the time of combustion would be.

TABLE I.

Size of Grains within the limits of mm.	Density	Time of combustion, in Seconds	Moisture, per cent.	Variation in burning, in Seconds
0.10-0.20	1.67	18.50	0.9	0.68
0.20-0.40	1.65	18.87	0.9	0.62
0.40-0.60	1.60	19.92	0.9	0.64
0.60-0.80	1.59	20.01	0.9	0.60
0.80-1.00	1.57	19.92	0.9	0.47
1.00-1.20	1.53	20.20	0.9	0.60
1.20-1.40	1.48	20.48	0.9	0.68

But this is not so; extended experiments in this direction apparently prove the contrary; for they show in each case that the cardinal virtue of a good compressed mealed powder, with a uniform combustion, is the small variation in burning.

Table II shows this difference with three experimental powders each of two different densities. It shows that the time of combustion increases with the density, but the variation in burning decreases, yet the difference is not significant. Hence it is established in the Austrian Regulations (specifications) that very high densities, at least as high as 1.8, should be attained.

These are measured by Holecek's volumeter (pycnometer) and the size of the grains is fixed at from 0.30 to 0.65 mm.

The gigantic advance in weapons, extending from the present speed of fire to the hitherto unapproachable range of the guns,

allows the artillery expert no rest, compelling improvement in guns and projectiles. Amongst the many methods, some completed and some only attempted, to attain this end, only two need to be taken into consideration by the powder maker :

1. The extension of the range of shrapnel over 2000 paces.
2. The introduction of automatic time-graduator or apparatus with a similar object.

As to 1, the increase of the shrapnel range depends chiefly on the length of the period of combustion of the time fuze. This can be accomplished in two ways, namely, with a *longer* powder column made of the same powder as that generally used; or with an ordinary powder column (ring) with a *slower burning*

TABLE II.

Kind of powder	Density of powder	Mean time of combustion, Seconds	Maximum variation in burning, Seconds
Compressed fuze-powder M 97.....	1.847 1.475	17.64 16.58	0.30 0.66
Compressed fuze-powder No. 93.....	1.870 1.806	24.94 23.50	0.18 0.73
Compressed fuze-powder No. 93.....	1.908 1.728	24.06 23.43	0.44 0.54

fuze-powder. It is well known, and proven by experiment, that the irregularity of the combustion,—the variation in combustion,—increases with a slower burning fuze. In general, artillerymen have chosen the first method of increasing the range of shrapnel and almost all modern field-pieces have their powder columns (rings) so lengthened that they (especially in the larger calibres) have two, three and often four superimposed fuze-discs, and these are permitted to burn away successively. Occasionally a special additional fuze, or supplemental fuze, is added to the built-up fuzes already mounted on the shell. The shrapnel range to point of burst is thereby carried over 5000 paces; the actual range is doubled.

It is obvious that this method, with which the fuze maker is particularly concerned, has its limits, and cannot be continued

until the successively superimposed fuze-discs equal half the weight of the shell. It is expensive, too, since the cost of the fuze alone is greater than that of the unregulated shell. Lastly it is not proved that a fuze of the generally-used powder burns better than a better constructed, carefully made, but slower burning fuze made of a special powder. The many ignitions and transferences of ignition, the various sectional and oblique piercings of the disc-fuzes, are, once for all, the greatest sources of error in the construction of fuzes; moreover, the variation in burning will always increase with the greater length of fuze.

However, simple black powder cannot be used, since all compositions of a similar kind will only give 18 to 21 seconds' duration of combustion for about 20 cm. of fuze.

Black grain powder in the proportions which should theoretically give a perfect decomposition of the separate ingredients, viz., 74.81 per cent. potassium nitrate, 13.33 per cent. sulphur and 11.86 per cent. charcoal, has a duration of combustion of 18.35 seconds and a variation of 0.41 seconds.

Powders of similar composition give similar results in different countries. The English "Time and Percussion Fuze No. 60" has, under the above circumstances, a period of combustion of 20 seconds for a 20 cm. fuze and can be set up to 5670 metres. The Italian double fuze, M. 1900, burns just as long and up to 5600 metres, while the Italian mountain guns are fitted with a fuze burning 21.4 seconds. The Russian aluminum fuze, of the types 1900, 1901, 1902 and 1903, has a double fuze-channel covering 22.8 cm., and burns for 22 seconds (or 20 cm. burn for 19.3 seconds) and is timed for 130 Saschenen. The extreme subdivision of $1/10$ * Saschenen, about 40 metres, marks the permissible variation in burning. This fuze is of excellent construction, and one of the best that is used in any army. Holland too has an aluminum fuze timed up to 5600 paces, and Servia one for 5000 paces, made by Schneider & Creuzot. Among German fuzes, the so-called Richter fuzes, the field shrapnel fuzes C/70 and C/72, have a minimum period of combustion of 15.8 seconds and a maximum of 28 seconds. The earlier single stage shrapnel fuzes filled with compressed powder, sometimes with

* Sic. in original, but as 1 Saschen = 7 ft., the figures are obviously erroneous. [Trans.]

mealed powder, burned for $9\frac{1}{2}$ to $10\frac{1}{2}$ seconds, just as long as the upper disc alone now burns.

It is evident from the above mentioned details, that almost all artillery have a special fuze-powder, which has approximately the same proportions as black powder; but, of course, this powder is not always satisfactory for special cases. For example, the shells of the high-angle-fire guns require slower burning fuzes on account of their slower flight. The United States of America alone uses the old mealed powder in its service combination-fuze, which is compressed into two fuze-discs with a total length of 18 cm. and a pressure of 480 kilograms per square cm. In Austria they have different fuze-powders with burning periods of 14 to 30 seconds in the double fuze M 93.

The question now arises whether it would not be simpler and more practical to give up the complicated and expensive building up of the three and four stage fuze-discs and return to the old method, and establish a slower burning fuze-powder, that would burn just as evenly as the compressed powder hitherto used. If the demands of the general staff upon the producer of shrapnel go much farther, they will compel him to this solution.

As to 2, the introduction of automatic time graduators would make the production of fuze-powders so difficult and complicated, as to become a game of chess (lottery). The reason is that with a slow-burning powder, and with the present fuzes which can scarcely be made any longer, the time subdivisions on the outer rim would be so minute that it would be impossible to avoid mistakes, even from a bad light, and this introduces a new source of error. It might perhaps be possible, since the subdivisions are so difficultly legible, to place them in two series, one over and one under a dividing line, so that whole divisions and halves should be above and the quarters and hundredths below. But that is outside the limits of this article. (Nonius.)

Such are the demands made by a slow burning fuze such as has been described, and how are they to be combatted?

1. It must burn as evenly as possible, *i.e.*, the greatest variations in burning of one group or series must be very small, or the difference of the period of burning between the longest and shortest burning fuzes, should be a minimum. This minimum is naturally dependent on the duration of the time of burning, and

must be deduced rationally from that; at the greatest it should only be one-fortieth or one-fiftieth of the fuze's total time of combustion when at rest.

2. The time of burning of a given length of fuze, must be sufficiently slow to correspond with the shrapnel's time of flight for a range of 6000 to 8000 paces. This can be attained by a fuze-length of 35 to 40 seconds' duration of combustion.

There results from these considerations,—taking the extreme range as 8000 paces,—a fuze-powder which requires about 40 seconds to burn away, when at rest, in a fuze-channel about 20 cm. long; and the variation in burning should not exceed one second at the highest for complete combustion. Since at such a long range the end velocity of the shell has dropped about 200 metres, the fuze-length should cover about 100 metres more, which is very little at such distances.

Now follows the cardinal question,—How can such a slow-burning, compressed fuze-powder be produced? There are two ways of doing it.

a. Changing the proportions—in which may be included the addition of such bodies as increase the fuze-powder's period of combustion without affecting its combustibility.

b. A decrease in the carbon-content of the charcoal used, which in fact is nothing else than an addition of wood-meal (partially burned charcoal) to normal powder.

AS TO *a.*

So far as concerns the proportions it has been previously shown that the mixture of potassium nitrate, sulphur and charcoal which makes the best propellant powder, when used as a burning (combustible) powder only burns for 18.35 seconds, with a variation of 0.41 seconds. None of the black powder burns over 23 seconds, and by mere abstract change of proportions it is not possible to increase the time of combustion more than 10 seconds with the best possible efforts of the manufacturer. In these experiments the customary decayed black alder-wood charcoal was used, containing about 72 per cent. of carbon. The experiments were carried out with six different mixtures, with the conditions as similar as possible, in order to study the influence of the potassium nitrate and the carbon.

So far as the influence of the sulphur is concerned, Table III.

varying only in the increased time of combustion, shows that an excess of sulphur, over 15 per cent., with the potassium nitrate practically constant and very little carbon, acts as a retardant; without, however, attaining the desired time of combustion (40 seconds) or the desired uniformity; except in the first and last experiment, where the variation was only $1/44$ and $1/45$ of the time of combustion.

TABLE III.

Experimental powder				Attained	
Percentage of mix			Density	Time of combustion, Seconds	Variation of combustion, Seconds
Potassium nitrate	Sulphur	Charcoal			
59	37.0	4.0	1.854	33.82	0.76
75	19.0	6.0	1.877	30.11	1.11
73	22.0	5.0	1.828	29.63	1.48
76	17.0	7.0	1.836	29.00	1.27
77	15.5	7.5	1.854	28.29	1.17
67	27.0	6.0	1.825	26.52	0.58

Moreover, with short periods of combustion, sulphur has no particular influence and gives no results when added within the limits of 2 to 15 per cent. Hence only the potassium nitrate and the charcoal act as retardants or accelerators. And actually within the limits of 70 per cent. to 80 per cent. for potassium nitrate, and 20 per cent. and 10 per cent. for charcoal an increase of the time of combustion is perceptible, with a minimum of about 13 seconds; and with 80 per cent. potassium nitrate, 10 per cent. sulphur and 10 per cent. charcoal, its maximum reaches 25 seconds.

The above refers to a decayed black alder-wood charcoal, burnt black, containing about 72 per cent. carbon; the same quality of white alder-wood charcoal gives a fuze burning 4 to 5 seconds slower, but also a somewhat greater variation in burning. The desired end, a fuze-powder burning for 40 seconds, cannot be attained by method *a*, merely by a change of proportions.

Moreover, the action of different admixtures does not recommend itself practically, although it is interesting to follow their

influence on the period of combustion and the variation in combustion, which is often difficult to comprehend. Those will be mentioned here with which experiments have been made in the K. u. K. Powder Factory.

Graphite.—The most important is graphite, which is added to quick-match powders to increase their time of burning in, certain percentages—in private (mercantile) factories up to 6 per cent. In small percentages this addition is hardly noticeable, yet the variation in burning is considerably less. It would almost appear as if the single, very finely divided, particles of graphite distribute themselves uniformly and regularly between the ingredients of the powder, and thereby arrest the accumulation of gas, and the increase of pressure, and so induce a more uniform combustion. Practically this agrees with the quick-match powder, the regular combustion of which shows comparatively very small variations as compared with fuze-powders, in spite of its less careful preparation and only one hour's mixing in the incorporating mills.

Graphiting.—The graphiting of a fuze-powder until glazed is, however, not to be recommended. (Graphiting is covering the powder grains with an extremely fine layer of graphite with a view to its better preservation.) A graphited powder can be pressed into a fuze-ring (channel) just as well as another, but the intimate incorporation of the separate powder grains to a compact fuze-train is not as perfect as might be wished. The small cavities in the fuze-train show this by their pitting, which is visible to the naked eye when a graphited powder is compressed.

Barium Nitrate.—At the K. u. K. Powder Factory the whole or partial replacement of the formerly exclusively used potassium nitrate by barium nitrate was tried. With barium nitrate alone in the normal proportion, the experiment gave a negative result, in so far that the fuze-ring could not be ignited; by replacing one-third [*sic*, query $\frac{1}{4}$?] of the potassium nitrate by barium nitrate, so that the proportions were potassium nitrate 57, barium nitrate 19, sulphur 6, and decayed black alder-wood charcoal 18 parts, the fuze burned 23.49 seconds and 39.09 seconds; in the first case the black alder-wood charcoal contained 72 per cent. carbon, and in the second case only 62 per cent. The variation of burning was 0.74 in the one case and 0.30 seconds in the other, $\frac{1}{32}$ and $\frac{1}{30}$ [*sic*. query $\frac{1}{32}$ and $\frac{1}{130}$?] of the

period of burning, thus it was still somewhat too large; but this experiment gave us something to think about.

In France and Belgium also they had attempted, at the suggestion of Captain Wynant, to replace 40 per cent., even 80 per cent., of the potassium nitrate by barium nitrate, by which they hoped to attain a less brisant (explosive) but more impulsive (propellant) force. This was obtained, but the solid residue was too great.

Steatite (Soapstone) and Brick-dust.—When these substances are added in small amounts, and in a finely divided condition to the powder, they do prolong the time of burning, but not in the same way as graphite. However, they fill the fuze-ring with ash, and thus diminish the apertures for the gases and finally smother the fire. Their use is only to be recommended with caution, and they have not given satisfaction at the K. u. K. Powder Factory in the experiments undertaken by the order of the K. u. K. Technical Military Committee.

In the old "Military Chemistry" by Captain Gottlieb Scherrer, it is stated that one-half of the powder burned in a gun-barrel is converted into gas, whilst the other half remains as a solid residue; later statements say that two-thirds of the original weight remain as solid residue. [Débus says about 56–58 per cent., Trans.] This is not important for fuze-powder, but only how much fuze is burned from the fuze-ring, and how much ash is left in the fuze-ring, and in what condition it is left. To ascertain this, many hundreds of fuzes, filled with the most diverse powders and then burned, were carefully weighed before and after burning—naturally only the fuzes under consideration.

The average weight of the compressed powder in the upper and lower fuze-discs before burning was 25.635 Gm. Weight of the residue in the fuze-channels, weighed immediately after burning,—12.614 Gm. The powder converted into gas then weighed 13.021 Gm.,—about one-half. The largest residue (14.509 Gm.) was obtained from an experimental powder which contained potassium nitrate, sulphur, and decayed black alder charcoal in the proportions 67:27:6. The smallest residue (11.50 Gm.) was yielded by an experimental powder with almost normal proportions (74:10:16).

It follows from these significant experiments that in spite of all there is not much to fear from choking the fuze-channel with

residues, and that there are several ways of diminishing the danger. Actually the daily weather conditions have considerable influence on the choking; if the weather is damp, the residue is softer and more easily expelled than in hot weather.

Vaseline.—Of those additions to fuze-powder which leave no residue, there are still to be mentioned the fatty oils, which the Swedish Major Unge, the well-known constructor of air-torpedoes, used as an addition to his propellant, though really only to prevent erosion.

In the K. u. K. Powder Factory from 1 per cent. to 4 per cent. of vaseline, liquefied by heat, was added to the powder during its manufacture, once in the pan of the incorporating mill, and another time during glazing, without any effect being noticeable. Moreover how this affects the ash deposit of this fuze-powder was not investigated at this time.

Compressed Gas-forming Substances.—There still remains the choice of one addition, which can possibly further the slow combustion of the fuze, without disturbing the uniformity of burning, and without increasing the residue. This is by the intermixture of those substances which consist only, or chiefly, of gas-producing ingredients, and by their combustion are decomposed into gaseous products, *e.g.*, sugar, alcohol, etc.; and the idea is aroused of compressing gaseous products into the fuze mixture and fixing them there in some way. So far experiments of this kind have not been made at the K. u. K. Powder Factory, and nothing regarding them is to be found in literature.

AS TO *b*.

The Influence of Different Well-burned Charcoals.—In the first place every wood for making charcoal for powder is of a different value in its action on the period of combustion, not only in respect to the place where it grew and the age at which it was cut; but furthermore the texture and the chemical properties of the different kinds of wood suitable for powder-making, change the period of combustion of the fuze-powder, even when they are so burned as to have the same content of carbon.

In the experiments at the Factory the following were considered: decayed black alder-wood, hazel, willow, white alder, poplar, and cork. The first two were apparently equal, and so

were willow and white alder; yet with the same content of carbon, the latter gave 4 to 5 seconds greater time of combustion and burned somewhat less uniformly. Poplar charcoal, burning somewhat slower, was excluded from the later experiments, because it frequently ignited in the ovens, though nominally better burned charcoal.

The behavior of the cork charcoal was peculiar, so that experiments with it would certainly have been continued, if there had been a possibility of burning the masses of cork (which were difficult to handle) to the proper degree in the present primitive plant. This was done as well as possible, and cork charcoal produced, which showed the mean carbon content of a retort to be about 42, 49, 52, 59, 62 and 72 per cent. But actually each charge of charcoal produced, was a mixture of more or less

TABLE IV.

	Period of combustion, Seconds	Variation in combustion, Seconds
Sample No. 1.....	31.44	0.73 (1/43 of the time)
Sample No. 2.....	39.37	0.90 (1/43 of the time)
Sample No. 3.....	41.17	1.02 (1/43 of the time)
Sample No. 4.....	47.49	1.12 (1/40 of the time)*
Sample No. 5.....	57.75	1.54 (1/42 of the time)*

* *Sic.* No. 4 should be 1/42; and No. 5 should be 1/38.

"burned to death" cork, and of cork not burned at all, with the most diverse gradations of charring; and in spite of this, results were obtained as good as the best, with high periods of combustion.

A complete fuze-powder was made from the above-mentioned cork charcoal, in the proportions 75 parts of potassium nitrate, 10 parts sulphur, and 15 parts charcoal, and burned as usual in the fuzes M 93 a.

With the exception of the over-burned charcoal, which showed very great irregularity in combustion, the period of combustion of the rest was as shown in Table IV.

It cannot be doubted that, if a uniform burning of the charcoal is desired, with rationally burned cork the actual variation in burning may be considerably decreased, within not too exacting limits. Furthermore, powder made of cork charcoal can be

unusually finely pulverized, mixes very intimately with the other ingredients, and can be easily compressed to a very high density; a density of 1.828 can be attained with cork-charcoal powder without trouble, at which density with other kinds of powder, the plates bend and fissures appear. Without any special procedure, the K. u. K. Powder Factory obtained an average moisture of 0.25 to 0.30 per cent. (that of other kinds of powder was 0.8 to 1.0 per cent.), and this powder, in the experiments carried on by the order of the K. u. K. Technical Military Committee, suffered no loss of its dryness and stability (good qualities) after two years in a damp magazine, while other powders, placed there at the same time, were almost unserviceable.

However, with the use of cork charcoal a *slow and uniformly burning fuze-powder* could not be produced; before that can be done better apparatus for coking (charcoal making) must be placed at the disposal of the powder manufacturer. A rationally working steam coke-oven seems the most suitable.

This end can be attained by various well-burned charcoals from decayed black alder-wood or white alder-wood, but even in this case a rationally constructed coking oven is necessary. Hitherto the proper value has never been placed on the use of different well-burned charcoals for black powder, as strictly speaking, only black and brown (red) charcoals are mentioned, without specifying their percentage of carbon. This neglect may have been of small consequence for a propellant powder, but becomes of importance when a fuze-powder is in question. It has been shown here that 1 per cent. of carbon affects the time of burning in the fuzes M 93 a to the extent of about one second.

Extensive experiments were made at the K. u. K. Powder Factory at Stein with alder-wood charcoal,—more particularly with decayed black alder-wood—in which the latter (with a carbon content varying from 27 per cent. to 80 per cent.) was always added to the mass in the same proportion of 15 parts to 75 parts potassium nitrate and 10 parts sulphur.

The results of several hundred experiments are submitted in the graphic form in Chart I. The curve of the time of combustion is shown by the ordinates; the base line, in which the percentage yield of charcoal is shown at equal intervals, is theoretically a curve similar to a parabola, in which the vertex expresses an approximate time of combustion of 15.5 seconds.

(A shorter time of combustion is not attainable with the above proportions.) Here the decayed black alder-wood gave a yield of 42 per cent. with 71.95 per cent. of carbon. In both the parabolic curves the times of combustion increase as much as the variations in combustion; and from Chart I it has been attempted to reach a longer time of combustion of 37.35 seconds, with a remarkable variation of 2.75 seconds ($1/14$ of the whole time) with the above-named proportions. This was attained with a very highly burned charcoal (80 per cent. yield and the very low carbon content of 53.85 per cent.). A more complete burning of the charcoal than a 27 per cent. yield (about 86 per cent. carbon content) can only be carried out in platinum retorts, otherwise it is hopeless.

This desired end may also be attained by more complete burning of the charcoal when further premises, to be investigated later, are worked out.

In fact the curve of the periods of combustion is not a parabola, but at about 67 per cent. carbon content it turns aside towards the higher ordinates, again reaches a maximum (at 76 per cent. carbon content) of 17.58 seconds period of combustion, and from there on falls again.

It is easy to assign the reason for this phenomenon (a parabola with the vertex depressed). At the time when about 67 per cent. of the decayed black alder-wood in the retort has become charcoal, the distillation of tar becomes very active, and the fluid tar-products boil, become solid and then burn to ashes. The ashes, and to some extent the unburned tar, collect in the interstices (pores) of the charcoal itself, and make it burn irregularly; it is for this reason that the periods of combustion of a fuze-powder, which is made from decayed black alder-wood containing 67 to 76 per cent. carbon, differ so much. As a matter of fact the curve on Chart I expressing the ash content, shows a not insignificant elevation exactly at the place where the depression of the vertex of the parabola expressing the periods of combustion, commences. This thesis will be still better confirmed later on by experiments on charcoal-making carried out with greater care and more exact analyses of the charcoal for powder. In this case there stood at the disposal of the K. u. K. Powder Factory in addition to their own laboratory, that of the Technical Military Committee and that of the Blumau Powder Works, yet

CHART I.

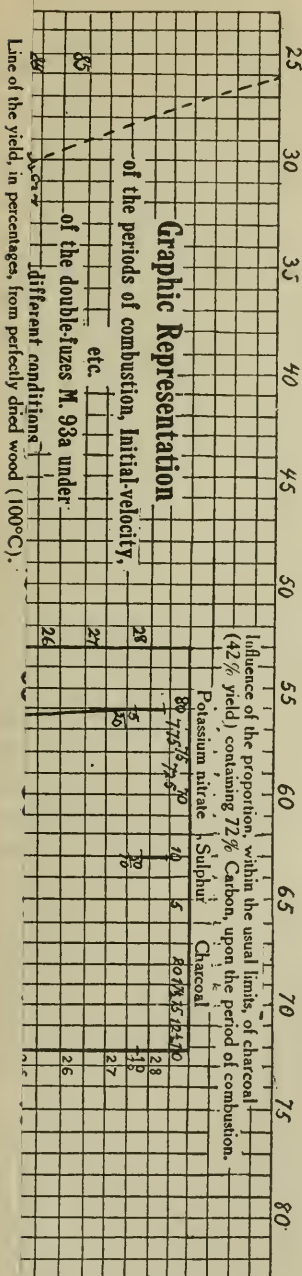
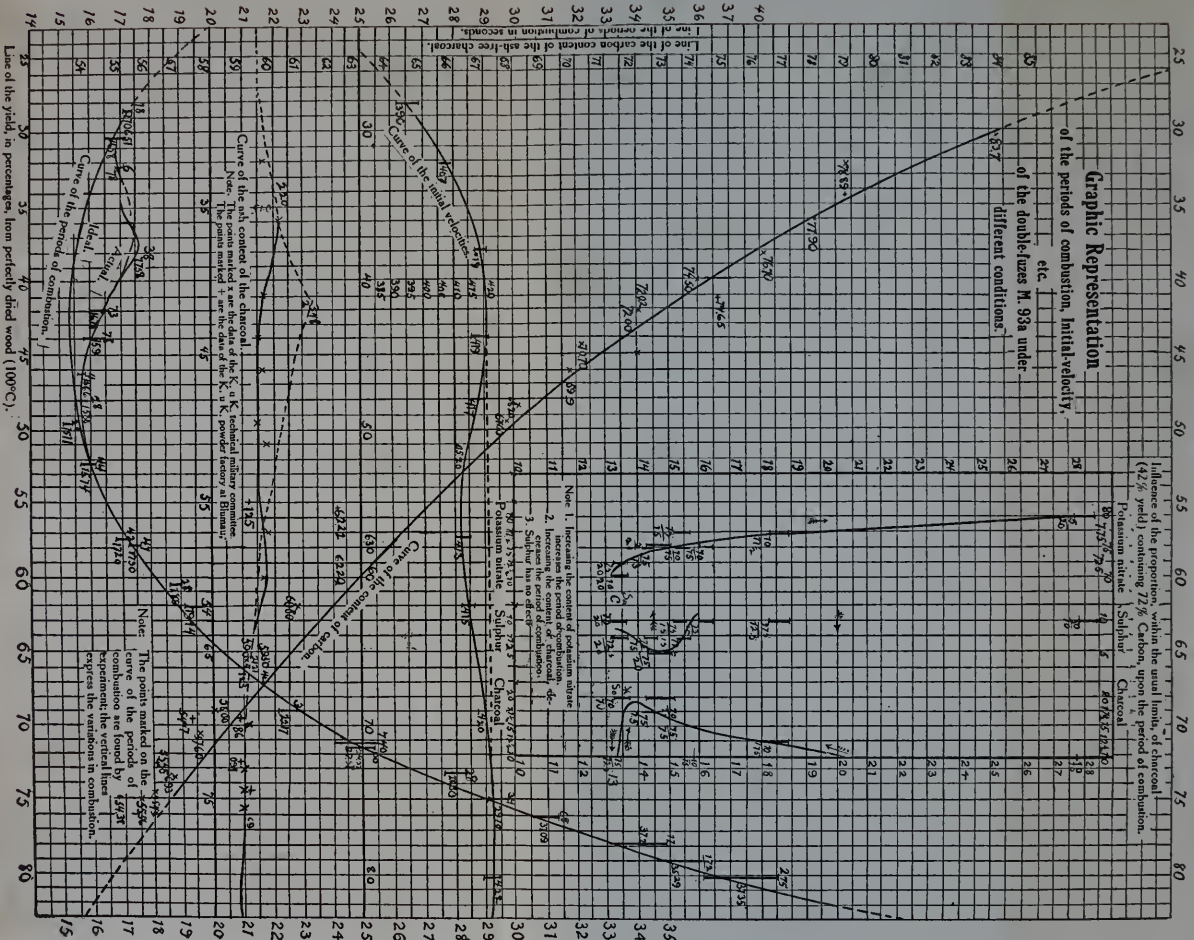


CHART I.



it appears from the curve of the ash content that all three statements differ from one another. One curve, inclined in a flat bow, cutting the period of combustion curve, expresses the carbon content of the decayed black alder-wood charcoal, also referred to in the base-line.

The conversion into charcoal of the decayed black alder-wood was just as difficult as that of the cork, and all the hindrances encountered there were also met with in this case. As far as these primitive means would allow, the law of the combustion of a fuze-powder, made from decayed black alder-wood, is shown by the data of the chart. All further burnings and investigation of fuze-powder, undertaken at the powder factory, and those pertaining to the production of decayed black alder-wood charcoal, were carried out on the basis of this chart and controlled by it. A better apparatus for charcoal making would only serve to make the data of the chart more accurate. The factory directorate has proposed the apparatus of Violette le Duc to the K. u. K. War Ministry of the Empire.

A further support of the assumption that still longer periods of combustion and smaller variations can be attained with charcoal burned systematically and in a manner free from objections, is the following circumstance:

The powder factory, in the course of its investigations, obtained possession of several hundred kilogrammes of the *broken prismatic* powder M 82 (for which at that time there was no use), because this powder, made by a celebrated firm, contained a very carefully made, high grade charcoal (52 per cent. carbon content). Used by itself as a fuze-powder this was not ignitable; but when mixed with black powder in certain proportions and thoroughly worked up, it gave periods of combustion of 40.21, 33.63, and 26.54 seconds, with variations of 1.12 seconds ($\frac{1}{36}$), 0.7 seconds ($\frac{1}{48}$) and 6.18 seconds ($\frac{1}{135}$ of the total time). [NOTE.—6.18 sec. or $\frac{1}{135}$ is evidently a misprint. Trans.]

From the foregoing illustration the possibility is presented of making a very slow-burning fuze-powder without using cork charcoal; yet in my opinion powder made with cork charcoal should give better results.

The question now arises how such a slow-burning fuze-powder can be produced. Practically the method is as follows:

Ingredients of the Powder.—The best double-refined potassium nitrate. Pure refined sulphur. For long periods of combustion barium nitrate is substituted for one-third [really one-fourth. Trans.] of the potassium nitrate. For charcoal, apart from cork charcoal, decayed black alder-wood should be used, or for longer periods of combustion, white alder-wood; and according to the requirements these should be burned to a carbon content of between 50 per cent. and 70 per cent. Finally there is no harm in adding 1 per cent. to 2 per cent. of the finest graphite and 1 per cent. of hot vaseline.

Proportions.—The normal proportions 75 : 10 : 15 are understood. Graphite and vaseline are added at the expense of the charcoal and sulphur. To increase the period of combustion ("slow" the powder) potassium nitrate is added, and the charcoal decreased; but that makes ignition more difficult. Sulphur changes nothing within the above-mentioned limits.

Pulverizing.—Well-burned charcoal, on account of its hardness, is first ground between millstones and then pulverized with small balls for about 2 hours alone, and then from 4 to 6 hours with the sulphur. The pulverization of the charcoal is the most difficult, and at the same time the most critical part of the whole production of fuze-powder.

Preliminary Mixing.—The preliminary mixing of a fuze-powder in mixing barrels with the aid of lignum-vitæ balls must be strongly disapproved, because a large number of the very finest splinters are split off the sides of the barrel and off the wooden balls and greatly contaminate the fuze. Instead of the preliminary mixing, customary with other powders, an hour's mixing with shovels in lots of 100 kilogrammes is recommended.

Incorporation.—The fuze-powder is incorporated for a longer or shorter time according to the season, but never less than 6 hours, so as to obtain an intimate incorporation and sufficient heat to soften the sulphur, as it binds better with the other ingredients in this condition, and helps the fabrication of the powder. (If vaseline is to be mixed in, this is best done in the incorporating mill.) To prevent dusting, 4 to 5 liters of water, —preferably warm rainwater,—are poured into the incorporating pan at short intervals.

Breaking-down (Corning).—According to the old custom, thus I name the conversion of the cakes which are very hard

and very adherent when they leave the incorporating mill, and which have very varying densities, into a coarse-grained but uniform powder.

For fuze-powder the lower sieves of the Le Feber granulating machine, in which the breaking-down takes place, should have a mesh not greater than 1 mm. at the most, for then the broken-down material can pass directly to the press, omitting the operation of after-mixing. The sides of the breaking-down machine, the corning-balls, all new tools and implements must be carefully inspected for any splintering of the wood.

Pressing.—The broken-down material, dried to 1.5 per cent. moisture (green powder), is pressed in an hydraulic press with the usual precautions. It is preferable to use small press plates (such as carry about 6 kg. rather than those usually used which carry 10 kg.) and only a few of them, and the pressure must be raised, until a density of at least 1.8, according to Holecek's Volumeter, is reached. This corresponds to from 300 to 500 atmospheres.

The most suitable size for grains from the cylinder graining machine is between 0.30 and 0.65 mm.

Glazing for 95 hours.

Whatever may be done in the way of *investigation and research* on fuze-powder, the present custom of burning fuzes charged with this powder first when at rest, and then of firing shrapnel furnished with such fuzes from guns, should decidedly be condemned; for in this way new sources of error appear, which may lie in the fuze (its construction, manufacture or adjustment) or in weather conditions, but are ascribed, altogether too readily, to the fuze-powder.

The investigation of fuze-powder should be limited to the *period of combustion*, the *uniformity of combustion* (difference of burning), and to the *ignitibility* of the powder; and this should be done under similar weather conditions, in a locality with a constant temperature. Experiments as to its range are independent of these matters. Then with a powder found to be suitable, as possessing certain constant factors, further experiments can be undertaken on the ignition and on the firing range; and all inaccurate functioning can be ascribed to varying conditions.

The simpler and more primitive these appliances for testing fuze-powder are, so much the better will they attain their object.

Simple steel shells, similar in shape to the old Bormann or Breithaupt shrapnel shells; simple tubes of a compressible metal, which are filled at a given pressure and cut off at a given length; or even calibrated tubes of a given length, which are pressed full of powder; these will always suffice if they are made alike and if their period of combustion,—from the ignition at one end until the fire breaks out at the other end,—is measured by an accurate chronometer. The arithmetical mean of the periods of combustion gives the required period; the difference between the longest and shortest period gives the maximum variation in burning; and the ease of ignition of the compressed powder is measured by a mechanism which causes an ordinary hammer to function. In this way undefined sources of error are avoided as much as possible, each day's production of powder is tested at a remarkably small cost, and only those powders found to be uniform are accepted and then blended. The result must be satisfactory.

Fuze Construction.—Although not strictly within the limits of this article, the modifications and constructions of shrapnel fuzes, which follow from the above-mentioned changes in the fuze-powder, must not be overlooked; for it is a *sine qua non* that the powder-maker and the fuze constructor must work hand-in-hand. A fuze with a slow-burning powder needed only a single ring, but with a somewhat larger burning surface, for previously existing ranges. As advances were made towards increased ranges for shrapnel, then simply a second ring sufficed, and consequently the many ignitions and transmissions of ignition, which are admittedly one of the chief causes of variations in burning, especially in fuze M 93 a, were avoided and eliminated.

Further it must be borne in mind that with a slow-burning powder the combustion must be facilitated; which means that the effect of the ash deposited in its course must be indirectly surmounted. This can be done by such a construction of the powder ring (channel), that at the beginning it is made broader and deeper, to give room for the passage of the back-streaming flame, and thus to neutralize the effect of the deposit of ash.

Thirdly, it is advisable to provide for a free air current, in addition to that which results from the flight—a single escape vent appears to be decidedly too small, or more vents should be provided.

Fourthly, the slow-burning fuze naturally demands a stronger *initial-ignition*. This principle was first established by the researches of the K. u. K. Technical Military Committee, since several fuzes were rejected by them as unignitable, which ignited without delay at the powder factory; so a remedy was grasped at, and the beginning of the powder column of such a fuze was supplied with a quicker burning mixture. Particularly the powder containing graphite was treated in that manner, which seemed best to suit that powder.

The old method of assuring the *retention and transmission of fire* by a complicated arrangement of quick-matches has fortunately been dropped and replaced by cylinders of compressed powder. But in order to offer still fewer sources of error, the orifices through which the fire is propagated should be filled with the finest grained powder. At any rate the elimination of quick-matches, and their replacement by loosely poured in powder, which is held in place by tin foil, seems to best meet the requirements, according to the investigations of the K. u. K. Powder Factory.

True Melting Points of Metals. M. VON PIRANI (*Ber. Phys. Ges.*, cccx, 48.)—The equivalent in black-body temperatures of metal surfaces is ascertained by optical pyrometry. To obtain the true temperature, Pirani uses the electrical resistance as an intermediate check, since this is not affected by surface conditions. The chief work was done on tungsten and tantalum. Taking the melting point of platinum as 1788° C., that of tantalum is 3100° and tungsten 335° C.

Ferro-Molybdenum Made by the Thermit Process. (*Eng. and Min. Jrnal.*, xc, 6.)—Ferro-molybdenum is now produced by the Thermit process and is coming into general use as a valuable alloy in high grade steels. Until lately pure molybdenum only was produced by this process, but to supply a demand, ferro-molybdenum is now being manufactured. The advantage of ferro-molybdenum over metallic molybdenum is that it does not oxidize, and that it can be more easily alloyed with steel, owing to its lower melting-point.

Tensile Strength of Aluminum Zinc Alloys. W. D. BANCROFT. (*Mech. Eng.*, xxv, 329.)—The alloys were made by melting 99.9 per cent. pure aluminum with "Bertha Pure Zinc" which had

less than 0.2 per cent. of impurities. When a thermocouple introduced in the melt indicated that the temperature had fallen to 50°C . above the freezing point, as indicated on Shepherd's diagram, the alloy was cast into an ice-cooled graphite mould, and quenched in ice-water immediately after solidification. Test pieces prepared in this way showed very high tensile strengths (25,000 to 35,000 lbs. per sq. in.). The 60 per cent. aluminum alloy having the maximum tensile strength of about 41,000 lbs. per sq. inch. The ductility of these alloys is very low, on 3-in. lengths below 5 per cent. elongation, but was considerably increased by annealing, with a corresponding diminution in the tenacity.

Action of Hydrogen on Carbon Monoxide. A. GAUTIER. (*Comptes rend.*, cl, 1564.)—When a mixture of hydrogen and carbon monoxide in the proportion $\text{CO} + 3\text{H}_2$ is passed through a heated porcelain tube the CO is reduced, even at 400°C . The production of steam attains a maximum at 1220°C . The maximum amount of carbon dioxide is found at 900°C . In most cases no carbon is deposited, but methane is produced. Further experiments of heating CO with steam at 550° to 800°C produced formaldehyde. The author applies these results to explain the composition of volcanic gasses.

Estimation of Radium. S. J. LLOYD. (*Jour. Phys. Chem.*, xiv, 476.)—Radium is estimated by the emanation produced in a solution of the radium salt in a known time. The effect of the presence of various reagents and precipitates in the solution of the radium salt is also investigated. For the accurate determination of radium by this method the presence of HCl or HNO_3 is necessary. If BaSO_4 or BaSO_3 is present in the solution, prolonged boiling or repeated determinations are requisite. In the case of freshly precipitated BaSO_4 the retention of the emanation is mechanical only, due to the entanglement of radium chloride or sulphate within the fine precipitate, the effect of heat being to release the radium and permit the removal of the emanation.

A New Resistance Furnace. F. A. J. FITZGERALD. (*Metal-lurg. and Chem. Eng.*, viii, 317.)—In this furnace the charge in the crucible is heated by radiation from resistance; in some forms it may be described as a furnace with a sealed reaction or heating chamber. Zinc has been experimentally produced in this type of furnace; and the efficiency of these furnaces has been determined at about 78 per cent. It is pointed out that in certain forms of electric furnace, the loss of electrically generated heat can be nearly eliminated by surrounding it with an envelope of burning gas. Experiments on large furnaces have shown that this arrangement is very economical.

AVIATION AND AEROPLANE MOTORS.

BY

HENRI PETIT,

Ancien élève de l'Ecole Polytechnique.

(Translated for the JOURNAL from *La Nature*.)

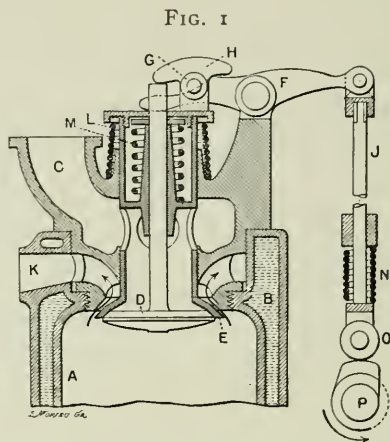
[The development of aerial navigation, almost unknown but five years ago, has with the adequate demonstration of its possibility and ultimate practicability proceeded with most rapid strides. In the account here presented, originally contributed to *La Nature*, of the requirements of the *fin de siècle* heavier-than-air machine, the author analyzes in detail the essential features of the power plant equipment and suggests a probable solution of the problems of future development.]

It has been said, and with reason, that the automobile alone made aviation possible; in fact it is the light and powerful petroleum motor employed in this vehicle that has given wings to mechanical birds.

One is tempted to assume that a very light motor is still indispensable to aviation. Progress made in the past two years is such that designs have, or at least *should have*, reached permanent types. The light motor is no longer a necessity. The recent exploit of Sommer who carried three passengers, that is, a useful load in the neighborhood of 450 lbs., is sufficient proof of this. The motor could evidently have weighed considerably more and the apparatus still have been capable of carrying the operator and one passenger. Does this mean that light motors are to be discarded and all efforts toward securing lightness abandoned? We entertain no such thought.

The light motor which made possible the flights with early apparatus will now make flight more certain and nearly free from danger. It is only too well known that all failures of the motor result in an immediate and often rapid descent which at times may be exceedingly dangerous. Notice also that the prominent aviators who undertake a cross-country flight select their course with care and maintain a very high altitude. Lambert, who ordinarily does not seek high altitudes, in soaring over Paris, was obliged to ascend to a height of more than 1600 feet.

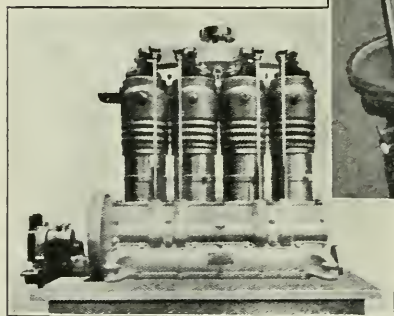
In lightening the motor it may prove possible (and that is probably the future solution) to equip the apparatus with



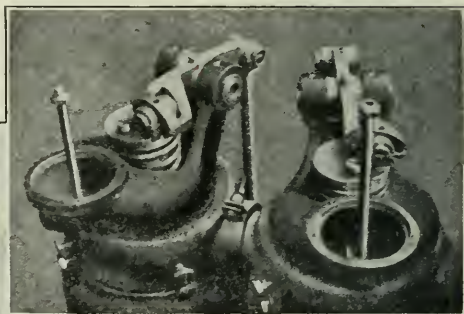
Panhard and Levassor concentric inlet and exhaust valves operated by a single cam.

FIG. 3.

FIG. 2.



Exterior view of Panhard-Lavassor 4-cylinder motor. Weight without cooling water, 210 lbs.; 35-45 horsepower.

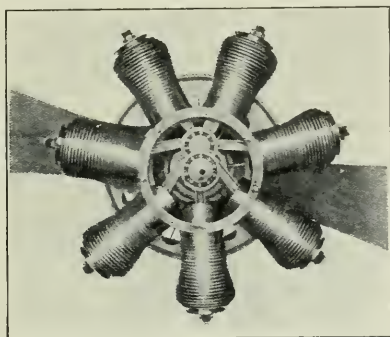


Exterior view of valve mechanism in head.

two motors each capable of insuring the motion of the aeroplane. In normal flight the two motors would be attached to the propeller through a double clutch, each operating at only half its normal

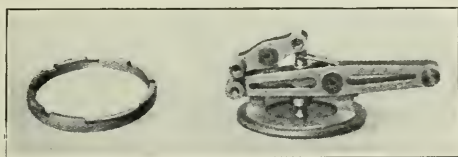
power. Should one of them fail the operator uncouples it, while the other driving with full power permits the flight to be continued until a favorable landing is reached. The low efficiency of two motors operating at half power will doubtless provoke criticism. It is known that the efficiency of an explosive motor diminishes somewhat rapidly when it operates at a power too far below normal. But less primitive methods than those found on existing engines may be employed for controlling the speed.

FIG. 4a.



One connecting-rod of the Gnome motor is integral with the head, the six others are pointed to the head.

FIG. 4b.



Exhaust-valve levers of Gnome motor.

Speed control by varying the lift of the exhaust valves for example, long in use on the De Dion motors, gives excellent results from the point of view of efficiency.

FUEL CONSUMPTION.—Fuel consumption has to-day acquired an importance little suspected but two years ago. Present-day flights are no longer measured in minutes; the hour has been exceeded by many pilots and it is reasonably safe to predict that the day is not far distant when the aeroplane will enter the field of touring. Notwithstanding all precautions, landing being

always a precarious matter, it becomes essential to avoid as far as possible the necessity to replenish the fuel supply during a trip. As the allowable weight of combustible is limited, a motor of high efficiency will become essential. A few figures will serve to emphasize this requirement.

A petrol motor consumes about 1.05 pints of fuel per horsepower hour. Let us consider an aeroplane, whose motor is developing 29.6 horsepower, moving with a mean speed of 37.3 miles per hour, an average performance of actual apparatus. The hourly consumption will be 32 pints, that is, 53 pints per 60 miles. Adding to this about 8.4 pints of lubricating oil, and we shall still be below actual results. Sustained flights by aeroplanes may

FIG. 4C.

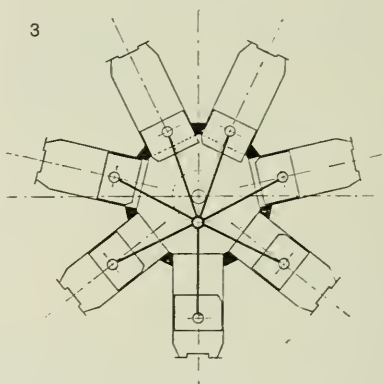


Diagram of connection in Gnome motor.

be regarded as the highest achievement in transportation. It is safe to expect that the aviator will aim to make a trip, for example, of 180 miles without stopping. He will require 95 pints of petrol and 25 pints of lubricating oil, weighing together, with their recipients, about 132 lbs., or nearly the weight of a passenger!

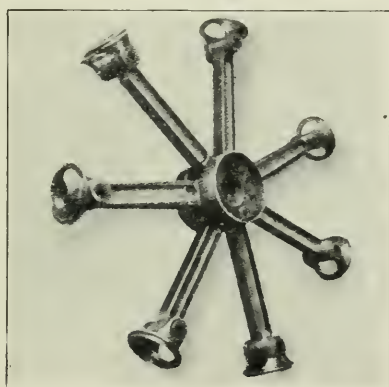
Notice, however, that fuel consumption in the majority of motors is appreciably greater; greater, it may possibly be said, in inverse ratio to the amount of study they have received with a view to securing extreme lightness. Thus according to the assertion of one manufacturer an early extra-light motor consumed 3.2 pints per horsepower hour. This motor, moreover, weighed scarcely more than 3.3 pounds per horsepower. A 49

horsepower motor, consequently, developing only 30 horsepower in normal flight would weigh 165 pounds and would require for a journey of 180 miles a supply of 285 pints of petrol and at least 42 pints of lubricating oil weighing, all told with tanks, about 308 pounds. The total weight of motor + petrol + oil thus reaches 470 pounds.

The motor whose fuel consumption was referred to above weighs but from 5.5 to 6.6 pounds per horsepower, that is, 330 pounds. The total weight in this case reaches 460 pounds. From a simple comparison of figures, the conclusion is obvious.

THE LIGHT MOTOR.—Be it as it may, it is interesting to investigate how a reduction in weight of a motor may be

FIG. 4d.



The seven connecting-rods of the Gnome motor.

effected. We shall consider this question in what follows. Three distinct methods are available:

1. Reduction in weight of each component member.
2. By better design, the elimination of a certain number of parts.
3. By increasing the power without increasing the ratio of weight to power.

Let us investigate in the above order each of the three methods.

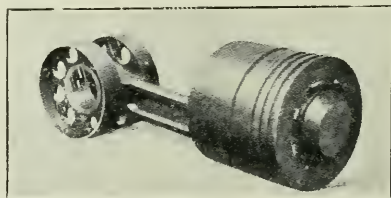
1. REDUCING WEIGHT OF PARTS.—The obstacles here are that the strength must remain unimpaired in reducing the weight and that the number of parts available is limited.

Cylinders.—The cylinders which in automobile motors are

almost always of cast-iron may be materially lightened if made of steel, which having greater tensile strength can be much thinner. Moreover, with cast-iron cylinders it is necessary to provide additional thickness to cover defects in the foundry. By separating the cylinder from its water-jacket and by placing the valves in the head, both the exterior and interior may be entirely finished on a lathe.

As to the permissible thickness, it is possible to reduce this to the dimension required by calculation of the stress on the material. However, in water-cooled cylinders the thickness should be sufficient to prevent a too rapid dissipation of the heat of the explosive gases and consequent considerable loss in efficiency. The plan of placing the valves in the head, on the contrary, favors high efficiency, the explosion chamber having thus a minimum of wall surface. With a view to keeping all parts of the cylinder an

FIG. 4e.



Master connecting-rod and piston of Gnome motor.

uninterrupted double curved surface of revolution the two valves have by some makers (R. E. P., Panhard, Pipe) been arranged concentrically with the axis of the cylinder.

The water-jacket can be made of copper or aluminum, crimped and brazed to the cylinder. No small difficulty has been experienced in making a durable joint with the cylinder, the difference in expansion of the two materials causing frequent leaks. It seems, however, that the results obtained by crimping followed by silver brazing, or even by a galvanic deposit, are durable and practical. Formerly the cylinders of certain motors were made partly of steel and partly of aluminum, but that construction is no longer employed.

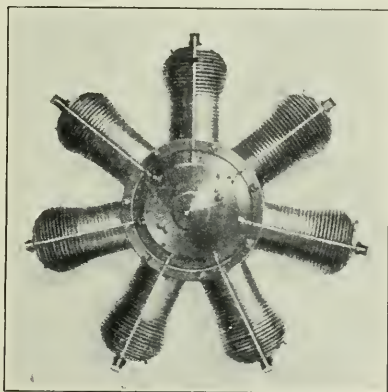
The Piston.—The piston may receive the same treatment as the cylinders to secure lightness, that is, cast-iron may be replaced by steel or even aluminum. The gain in lightness here is rela-

tively small but it permits of a high rotative speed, which, as will be presently seen, increases the power per unit of mass.

Frame.—The housing can be considerably lightened by the adoption of a special arrangement of cylinders. It is thus, in the rotative *Gnome* motor, reduced to its ultimate simplicity.

Fly-wheel.—It is not difficult to save in weight on the fly-wheel, without reducing its moment of inertia. For this, it has sufficed to concentrate its mass at its periphery and to increase its diameter. In the motor, Dutheil and Chalmers, for example, it consists of a rim of steel connected to the hub by steel spokes as in a bicycle wheel.

FIG. 4 f.



Exterior view of Gnome motor.

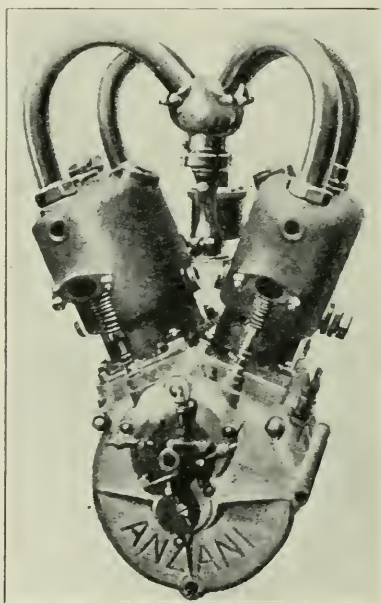
Accessories; Radiator.—The cooling system has been the object of many attempts towards simplification. Many designers, adopting air-cooling, eliminate it almost entirely. It is reduced, in that case, at most, to a fan which forces the air through a brass jacket embracing the cylinders. In the rotative *Gnome* motors the displacement of air by the cylinders insures an adequate cooling effect.

In water-cooled motors the radiator with its supply of liquid constitutes a considerable weight. It has been greatly reduced, first by the construction of special extra light radiators, which arranged either under the wings (*Santos-Dumont*) or on the body (*Antoinette*) of the aeroplane, then in reducing to a minimum the quantity of water. Thus, in the *Antoinette* apparatus,

the radiator is intended not to cool the water but to condense the steam which escapes from the cylinder-jacket.

The above comprise nearly all the reductions in weight that one may hope to effect on the component parts of the motor. Connecting-rods, valves, and cones have been pared down by automobile motor designers to the limit of lightness. As they say in shop argot they cannot be *skinned* any further.

FIG. 5.



Four-cylinder Anzani V-motor.

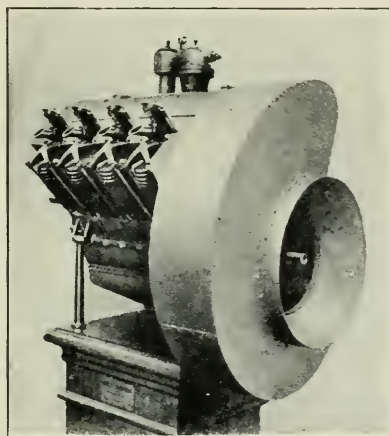
2. ELIMINATION OF CERTAIN MEMBERS.—The automobile motor as we understand it carries no superfluous members. Each has a determinate function and if a single one of them is removed the mechanism stops. To accomplish a lightening by the method of elimination, the separate members of the motor must be so correlated that one of them can fulfil the functions previously distributed among several others. Along this line of attack beset with obstacles little progress has been made.

Non-essential Accessories.—First, those accessories that are not absolutely essential have been suppressed, such as the muffler

and exhaust piping. Even the carburetor has disappeared in some motors and with it the admission piping (Antoinette, Wright). In these the fuel is injected directly over the valves.

It is not alone, however, the craze for extreme lightness that has prompted the designers of these two motors in this radical suppression. The carburetor is at present an object of attack from numerous critics who are even disposed to treat it as a scape-goat. It is, nevertheless, a question whether its defects are as serious as its critics would have us believe.

FIG. 6.



Renault aviation motor.

Fly-Wheel.—The fly-wheel, already lightened in some motors, has been entirely omitted in many others. It is understood that its function is to regulate the action of an explosive motor whose torque is very variable, the more so as the motor is equipped with a smaller number of cylinders. On motors with six cylinders the fly-wheel ceases to be theoretically necessary, the torque is in effect always positive and never falls to zero. *A fortiori* with eight cylinders it may be entirely dispensed with though it is still, shall we say, wisely provided on a few motors of this class. The omission of the fly-wheel is not unattended by disadvantages. While apparently suppressed, the propeller keyed to the crank-shaft replaces it and absorbs the shocks due to variable and sudden torque of the motor.

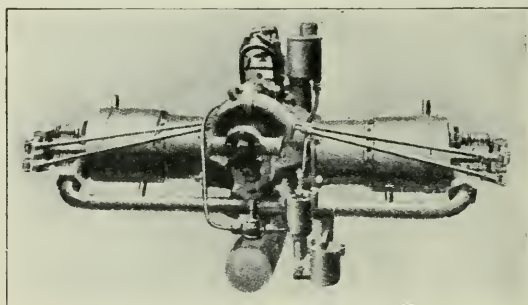
A better solution is embodied in the rotative motors (Gnome, Vol. CLXX, No. 1018—23

Burlat). In these motors it is the mass of the cylinders which revolve and, consequently, replace the fly-wheel. There is here no omission but purely and simply the replacement of one member by another without interfering with the proper functions of the latter.

Crank-Shaft.—While the crank-shaft has not been entirely suppressed, it has been reduced to next to nothing in rotative motors. All the connecting rods are attached to one or at most two crank-pins. Whence a reduction in weight of the crank-shaft as well as the connecting rod heads which frequently merge into one.

Cams and Valves.—M. Esnault-Pelterie has not considered negligible the weight of cams and valves. In his seven-cylinder

FIG. 7.



Duthiel-Chalmers double opposed motor.

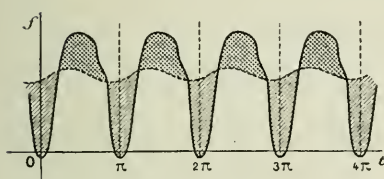
motor a single cam controls the entire distribution. The concentric valves are lightened and so arranged that their cooling is a simple matter.

3. INCREASE OF THE RATIO OF POWER TO WEIGHT.—The increase of power per unit of mass is far from being a new problem. The designers of the racing cars intended to compete for the Gordon-Bennett cup, when a maximum weight was specified, have exhausted the subject and there remains little to be done for aviation motors.

High power per unit of mass is allied in many ways with good efficiency. In other ways it is entirely independent of efficiency. A discriminating choice among these contradictory conclusions is needful to produce a motor of high unit power and of high efficiency.

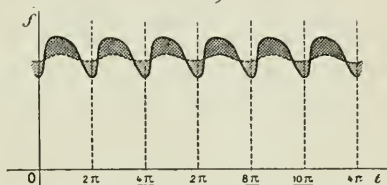
Without entering into a discussion of all the data of the question we shall be content to announce the conclusions. The form of what is known as the characteristic curve of an explosive motor is familiar; it expresses the power of the motor as a function of its angular velocity (Fig. 10). Clearly the power first increases with the speed, reaches a maximum, then decreases rapidly with any increase of speed. The velocity Ω corresponding to the maximum power, P , is known as the critical speed. It is conceivable that the further towards the right the position of the

FIG. 8.



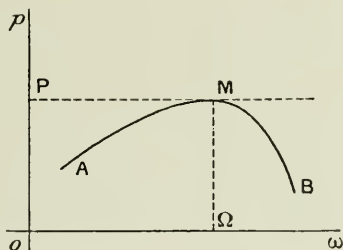
Full curve, tangential effort; dotted curve, tangential resistance.

FIG. 9.



Showing the marked improvement in uniformity of torque over that of a 4-cylinder motor.

FIG. 10.



Characteristic curve of explosion motor. Abscissæ, angular velocity; ordinates, power.

maximum point, M , assumes, the greater will its value become. Hence the search will be made in other terms to find the high-velocity motor.

Satisfactory efficiency requires high piston speed; hence, at the same time, high angular velocity and a long stroke. Lengthening the stroke increases the weight without much gain in power. Let us also inquire, on this point, into the lessened efficiency. Nearly all aviation motors are *square*, that is, bore equal to the stroke. High compression increases the efficiency and also the

unit power. Nevertheless it does not appear that in this direction the question has been fully investigated for aviation motors. The maximum of compression 90 to 100 pounds per square inch, which with care can be attained with petrol, is far from having been reached. This is due, without doubt, to the difficulty of cooling a high-compression motor when employed for aviation.

The ruling temperature in aviation motors, which is as high as possible, while again favorable to efficiency, is offset by an excessive consumption of lubricating oil. In this, as in all things, a happy medium should be observed.

In conclusion, the light motor will be a high-speed motor, the compression will be moderate. The cylinders will be of steel with vanes or a separate water-jacket. It will be equipped with at least six cylinders, generally seven, to avoid the use of a fly-wheel.

In a future article we shall study the practical realization of those conditions among various designers and a classification of their motors.

Thulium. C. JAMES. (*Amer. Chem. Soc. Journ.*, xxxii, 517). About 250 Gm. of the bromate of Cleve's thulium were obtained by the continued fractionation of those rare earth bromates more soluble than erbium bromate. Thulium salts are of a pale bluish-green color, which is readily changed by minute amounts of erbium, the solution becoming first yellowish-green, then yellow, colorless, and finally pink with the increase of the proportion of erbium. The author is determining the atomic weight of the metal and is continuing the fractionation to ascertain if more than one element is present.

Course of Radio-active Projections. L. WERTENSTEIN. (*Comptes rendus*, cl, 869).—It is known that α -particles are propagated in a practically straight line to the point where they stop, each kind of α -particles having a well-defined path. The author has investigated the case of the projection of RaB by RaA in order to ascertain whether the projection exhibits an analogous character. The results show that the RaB particles traverse a definite path equal to 2 mm. at 45 mm. pressure, and that the length of this path is inversely proportional to the pressure, the product of path and pressure being about 90. At the normal pressure the path is about 0.1 mm. corresponding with a penetrability 400 times less than that of the α -rays of RaA.

AERIAL PROPELLERS AND SOME TEST RESULTS.

BY

CHARLES EDWARD LARARD, M.I.,

Mech. E., Assoc. M. Inst. C. E.

AND

ROBERT OLIPHANT BOSWALL, B.Sc.

(Slightly abridged from London *Engineering*.)

[The helical propeller, be it hydraulic or aerial, acting as it does upon a yielding and unconstrained medium, is a device offering exceptional difficulty of analysis from strictly theoretic consideration as is well known. Marine engineers have therefore resorted to the more direct method of experiment to secure the requisite data on the subject. This paper is an account of the application of the same process to aerial propellers, the results of which can scarcely fail to prove of value in selecting an aerial propeller.]

1. AIRSHIP stability and safety will be found to be very largely dependent on an exceptionally high translational speed, which will necessarily reduce the risk of flight due to prevailing or sudden air currents to a minimum.

2. The best propeller for a given aeroplane, the propeller shaft of which rotates at the highest economical speed for the particular engine mechanism, is that propeller which produces maximum translational speed per brake horsepower or, in other words, that propeller which gives the greatest thrust per brake horsepower.

Hence it follows that in the design, construction and testing of propellers, we must have regard to:

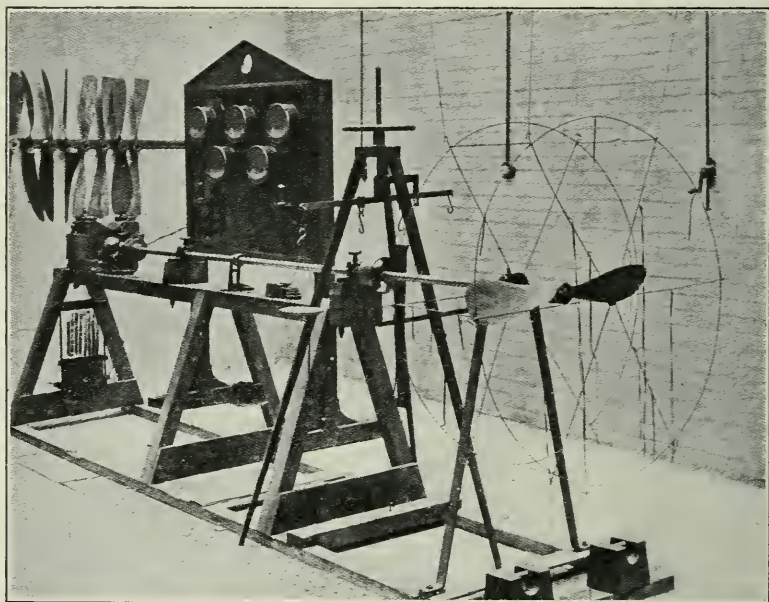
1. The rotational speed of the propeller.
2. The total thrust and the thrust per brake horsepower.
3. The aerial or translational speed of the propeller.

With respect to the design and construction of aerial propellers, it is perhaps too great to expect, in the present state of our knowledge, that any theory elaborated can do more at the present time than indicate forms of propellers to be constructed with a view to the experimental determination of their

relative values. In fact, it is not too much to state that, in the first instance, any results of value will have to be obtained from the experimental side of the problem, propellers being designed, constructed and tested and unsuitable forms eliminated on the test results.

The question then arises as to which is the best experimental

FIG. 1.



Apparatus for testing aerial propeller.

method of attack in testing propellers for aerial use. Three methods suggest themselves:

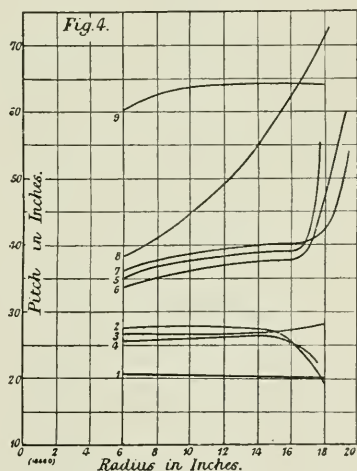
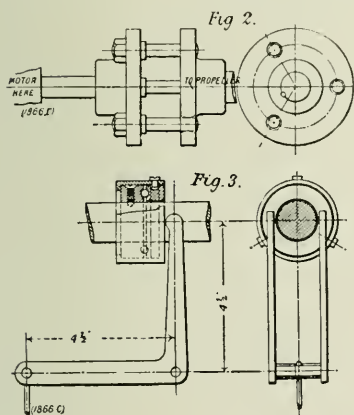
1. The static test method.
2. The whirling table method.
3. Testing under conditions of aerial flight.

The first two methods only have been attempted as far as the authors are aware; and while the third method is undoubtedly the ideal one, the difficulties have apparently prevented its being resorted to.

Nevertheless the difficulties are not so great as would appear at first sight; the practical solution of the problem being chiefly

a financial question. What is wanted, provided the necessary funds are available, is an experimental track for combined aeroplane and propeller-testing similar to that previously suggested by the authors. Such a track for the testing of aeroplanes, engines, and propellers under conditions approximating, in many respects, to actual flight has in the authors' opinion become an urgent necessity. Even from a financial stand-point the difficulties are not insuperable.

During the winter session 1909-10 provision had to be made for the laboratory work for students taking the aeronautical classes being held in the Mechanical Engineering Depart-

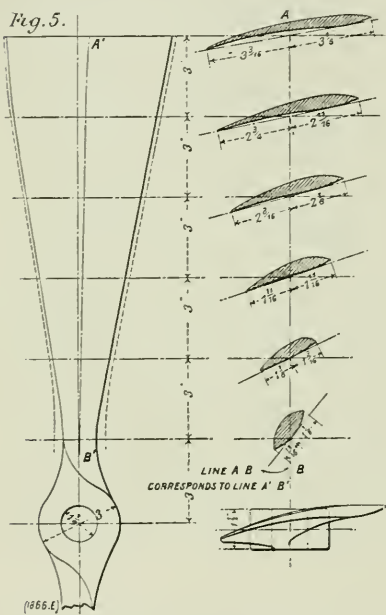


ment at the Northampton Institute, Clerkenwell, E. C., and among other experimental work carried out with the assistance of the students and staff was a series of tests on aerial propeller models with the object of obtaining definite information and comparative results for differently shaped models. In all twelve propellers were tested and the chief particulars for nine propellers and the results derived from the tests are given in the following pages.

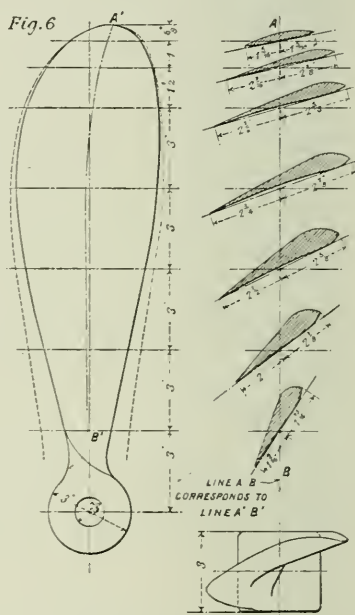
Testing Apparatus.—The important question of floor-space available made it impossible at the time to consider any other apparatus than for the static tests which, although not giving the means for determining actual thrust and horsepower under

what may be termed "ideal conditions"—that is to say, conditions attaching to actual flight which can only be obtained by the use of apparatus of the whirling table or continuous track type necessitating a large ground area—yet enables a student to compare results given by different forms of blade surface and to arrive at some definite conclusions as to their relative values as a means of propulsion.

The apparatus used is illustrated in Figs. 1 to 3. In its construction the apparatus already available in the workshop and



Propeller No. 1; right hand.

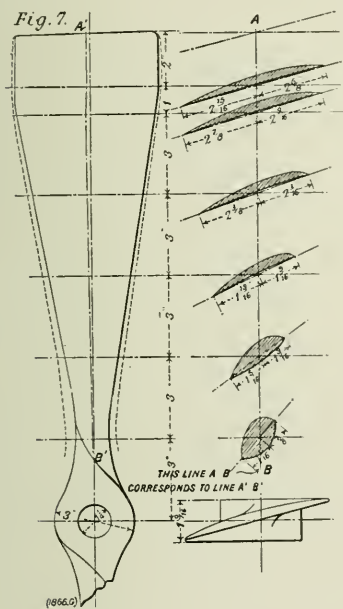


Propeller No. 2; right hand.

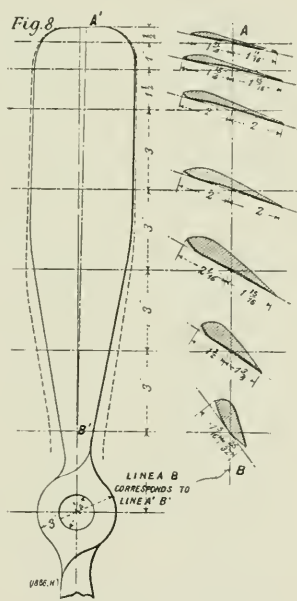
laboratory for other work was assembled and pressed into use pending the design and installation of a more suitable plant at a later date. It was thought that a few tentative experiments on this important subject would be of value as indicative of the line to adopt and the scope of work for future and more extensive research when the necessary funds are forthcoming.

The apparatus as erected and finally used for the purpose of these experiments consists, essentially, of a light steel shaft $1\frac{1}{4}$ inches in diameter carrying the propeller at its tail end

and driven by a 2-brake-horsepower electric motor (15 ampere, 100 volts) of the shunt-wound type mounted on a strong wooden framework. The shaft is supported in three plummer blocks provided with lubricators, the actual bearing area being small. The connection between the propeller shaft and the motor shaft is made by a coupling which permits of a free but small axial movement (see Fig. 2). A steel flange keyed to the motor shaft has three projecting pins which engage with corresponding holes in a flange keyed to the propeller shaft. These



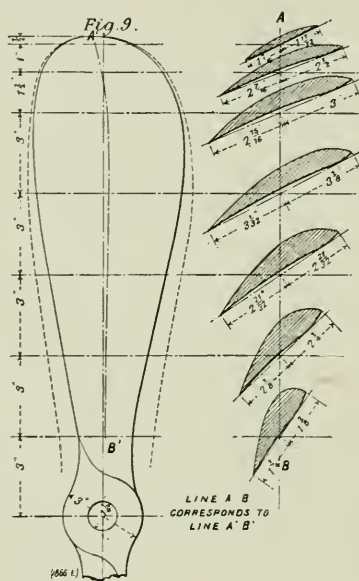
Propeller No. 3; right hand.



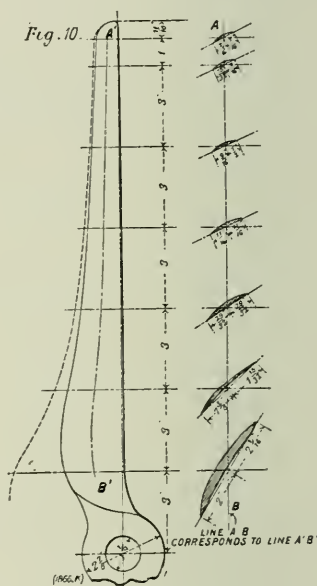
Propeller No. 4; left hand.

holes are slightly larger than the pins so that practically line contact occurs with the pins. The bearing at the propeller end of the shaft is supported on a light-metal framework so that the flow of air to or from the propeller, according to the direction in which it is rotating, may be influenced as little as possible. This precaution was found to be somewhat unnecessary, in view of the fact that a surface of almost equal diameter to the propeller caused practically no effect on the thrust even when brought quite close to the rotating propeller. The ap-

paratus was also erected as far as was necessary from both walls and floor of the laboratory to prevent any appreciable effect that they might have on the air currents. The thrust is taken and measured by means of a bell-crank lever for carrying the weights placed in a scale-pan, the vertical arm pressing on a ball-bearing thrust-block secured to the shaft, an arrangement which insures a minimum of friction (See Fig. 3). Weights are placed in the scale-pan hung from the horizontal arm to equalize the thrust. To prevent the shaft from having



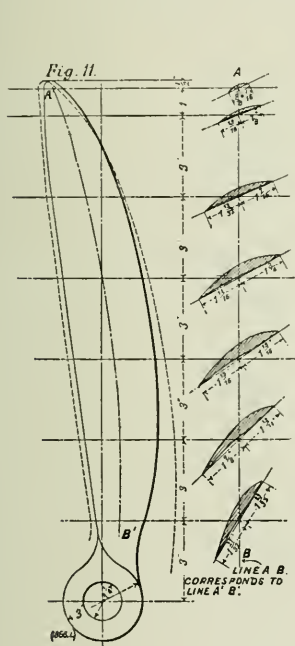
Propeller No. 5; right hand.



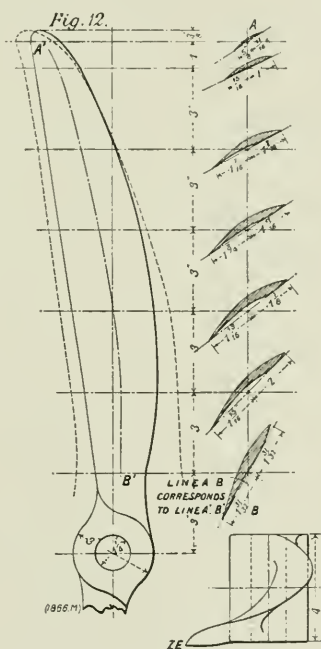
Propeller No. 6; right hand.

too great a lateral movement, and to provide a means for obtaining the necessary adjustment between the thrust and the balancing weights, a collar was fixed on the shaft on each side of the bearings allowing an axial movement of not more than $\frac{1}{4}$ inch. In the experimental determination of the thrust sufficient weights were added to enable the shaft to rotate with neither of the collars touching the bearing. In this position of equilibrium it was found that an addition of only 0.05 lb. was sufficient to disturb the balance, showing that the friction laterally during rotation was so small as to be negligible. The question

of static friction does not, of course, affect the case at all. The normal running of the motor was 1200 revolutions per minute but a large variation of speed was obtained by using in conjunction with the usual starting switch with five stops, an additional resistance frame with fourteen stops giving any range of speed required. An ammeter and voltmeter were also connected in the circuit. The measurement of the actual horsepower necessary to rotate the propeller at different speeds caused



Propeller No. 7; right hand.

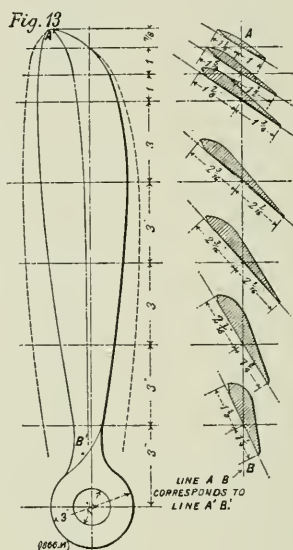


Propeller No. 8; right hand.

some little difficulty. The simple determination of the horsepower absorbed by the motor, as indicated from the instruments in the motor circuit, can only give an approximate idea of the horsepower actually absorbed by the propeller, owing to the great variation in efficiency of the motor when running at varying loads and speeds. To determine the horsepower with some degree of accuracy the following device was resorted to: A small cast-iron pulley was keyed to the shaft and a Soames band-brake used. During the measurement of the thrust given

by the propeller the brake was not used, but observations were taken for thrust, the amperes and volts as indicated by the instruments and also the speed by means of a direct reading speedometer.

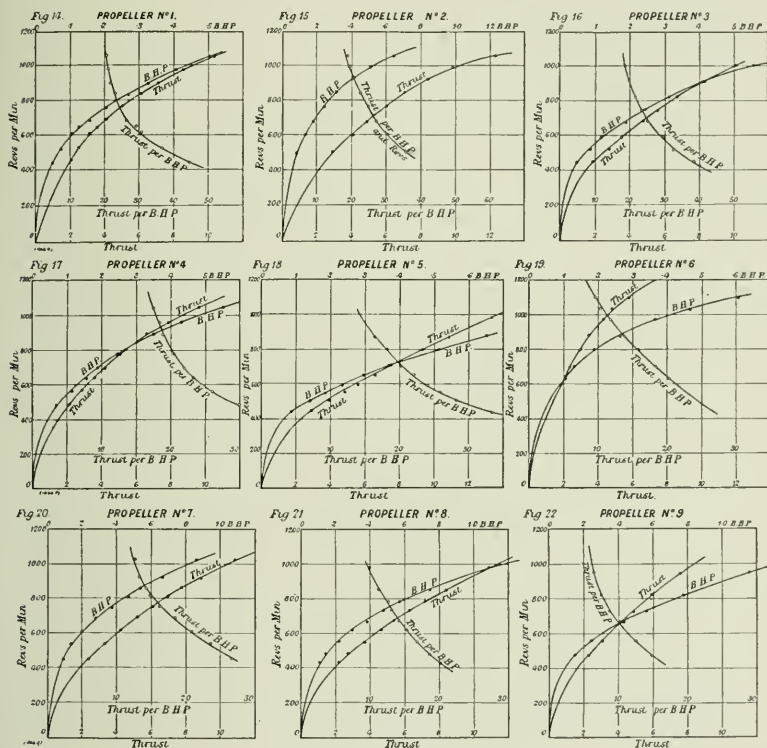
The propeller was next removed and the brake-band placed round the pulley and a careful adjustment of the load on the brake-arm made until the motor-instrument readings and speed were the same value as before. Although the reading on the voltmeter forms a direct means for ascertaining that the speed was the same as before, it was found advisable to again check



Propeller No. 9; right hand.

the speed with a speedometer, making any slight alteration of the brake load due to any small alteration of the voltage in the mains. To obtain the same resistance in the circuit for each of these tests, the position of the two switch levers was ascertained when making the first test and the same position used in the second test. To maintain the same frictional conditions, the load acting on the thrust bearing was kept the same in the two corresponding tests, and, to get over the difficulty of the pressure along the shaft not being balanced by the propeller thrust, and so causing one of the collars to press against one of

the bearings, the two flanges were clipped together so as to prevent the shaft having any axial motion, the collars being out of contact with the bearing. Under these conditions the efficiencies both electrical and mechanical must be the same in each case and the horsepower measured by the brake will be the actual horsepower measured by the propeller.



Results of tests of aerial propellers.

To obviate the necessity of double readings required by this method to eliminate the efficiency errors, it is suggested that a balanced motor be mounted on ball bearings and provided with an arm and suitable mechanism, by means of which the torque may be measured directly. This alteration would then have no need of great experimental manipulation to obtain good results, a point which is of some importance with aeronautical students who may not have had much laboratory train-

ing; at the same time the experiments could be carried out with despatch. Some form of dash-pot arrangement might be a necessity to damp any inconvenient vibrations which might

TABLE I.—PARTICULARS OF AERIAL MOTORS TESTED

No. of propeller	Diameter in inches	Projected area in square inches	Developed area in square inches	Pitch	Remarks
1	36.25	115	122	About 20 in. constant.....	Slightly concave driving face. Broad at tips. Corners left square
2	36	120	141	Constant pitch of 27.5 in. up to 15 in. radius, decreasing therefrom to 20-in. pitch at tip	Concave driving face. Maximum width about two-thirds lengths of blade. Tips rounded off
3	36	107	118	Constant pitch of 27 in. up to about 15 in. radius, increasing therefrom to 28 in. at tip	Driving face almost flat; leading and trailing edges straight; and width constantly increasing to tip
4	36	96	110	Gradual increase of pitch from 25.5 at 6-in. radius to 26.5 in. at 14-in. radius, and a decrease therefrom to 22 in. at tip	Slightly concave driving face; leading and trailing edges straight; and width increasing to about half length of blade, followed by a constant width of tip
5	36	106	133	Gradual increase of pitch from 35 in. at 6-in. radius to 39.4 in. at 16-in. radius, followed by a rapid increase to 56-in. pitch at tip	Concave driving face; width increasing to about three-quarters length of blade; tips rounded off; plane of blade bent towards driving face at tips
6	39.375	56	66	Gradual increase of pitch from 34 in. at 6-in. radius to 37.5 at 16-in. radius, followed by a rapid increase to 60-in. pitch at tip	Leading edge straight; driving face slightly concave; width of blade decreases rapidly to about half length, then slightly narrows at tip
7	39	83	104	Gradual increase of pitch from 36 in. at 6-in. radius to 40.5 in. at 17-in. radius, followed by a rapid increase to 54.5 in. at tip	Usual form of blade, straight trailing edge; maximum width at half length and converging to a point at tip
8	38.75	89	102	Rapid increase of pitch from 38.2 in. at 6-in. radius to 72.5 in. at tip	Form of blade similar to No. 7
9	35.75	72	109	Increase from 60-in. pitch at 6-in. radius to 64-in. pitch at 12-in. radius, followed by a constant pitch of 64 in. to tip	Concave driving face. Usual form of blade converging to point at tip. Plane of blade towards driving face at tip

occur at high speeds but to what extent any vibration would affect such an arrangement is purely a matter for experimental investigation.

Propeller Forms.—All the propellers tested were made by the firm of Messrs. Handley Page, Limited, aeronautical engineers, of Creekmouth, Barking and 72 Victoria Street, S. W., and loaned to the authors for the purpose of these experiments by Mr. J. Handley Page. For convenience of reference, the principal details of the propellers are given in Table I while their exact forms are given in the illustrations (Figs. 5 to 13). Fig. 4 represents graphically the relationship between the radial pitch and radius for each one of these propellers. The projected area and the developed area for the several models are shown in the illustrations (Figs. 5 to 13), by the full thick line and the dotted line respectively, these areas for each blade being, in addition, tabulated in columns three and four of Table I.

TABLE II.—RESULTS OF TESTS

Propeller	1	2	3	4	5	6	7	8	9
1000 revolutions:									
Thrust.....	9.0	10.3	10.05	8.7	13.8	4.6	10.5	11.6	8.4
Horsepower.....	0.43	0.53	0.55	0.48	0.98	0.41	0.83	1.21	1.33
Thrust per horsepower.....	21	19.5	18.5	18	14.1	11.2	12.7	9.6	6.3
800 revolutions:									
Thrust.....	5.4	6.5	6.4	5.4	9.4	3	6.8	7.6	5.7
Horsepower.....	0.23	0.28	0.29	0.265	0.53	0.195	0.44	0.62	0.73
Thrust per horsepower.....	23.5	23.2	22	20.4	17.7	15.4	15.5	12.3	7.80
600 revolutions:									
Thrust.....	3.15	4.05	3.8	3.2	5.6	1.9	4.1	4.4	3.5
Horsepower.....	0.10	0.135	0.135	0.13	0.24	0.09	0.195	0.27	0.305
Thrust per horsepower.....	31.5	30	28.3	24.6	23.4	21.2	21	16	11.50

Test Results.—All the experimental results for the tests on the nine propellers selected are shown graphically in Figs. 14 to 22 and, in addition, tabular results are given in Table II, for three speeds—600, 800 and 1000 revolutions per minute.

Comparison of Results.—The best of the test results, considering only the thrust per brake horsepower are given as will be seen by reference to Fig. 23, by the propellers Nos. 1, 2, 3 and 4 with the small pitch angles and the greatest blade area near the tips. Propeller No. 1 has the least pitch which is practically constant; propellers 2 and 4 have constant pitch up to a radius of about 15 inches and then undergo rapid reduction of pitch, while propeller No. 3 has constant pitch up to 15 inches with slight increase near the tips.

If, however, results are judged from the consideration of

maximum total thrusts irrespective of horsepower, then propeller form No. 5 with the broad and more rounded blade and larger angle comes out the best, with the usual forms Nos. 7 and 8, coming next. The experimental results may be taken as some confirmation of the following theory:

In the case of a static test, the propeller blade meets the air at an angle which corresponds to the pitch angle while, in the case of a moving test, the angle of attack depends on the ratio between the forward and rotational velocities of the blade. Let

A = Area of small element of the blade which will be considered plane;

θ = angle of attack or pitch angle;

R = radius;

V = velocity in feet per second;

μ = coefficient of friction.

Then the forces acting on the small blade element are (1) a pressure P which assumes to be normal and is by Duchemin's law,

$$KAV^2 \frac{2 \sin \theta}{1 + \sin^2 \theta};$$

(2) a frictional resistance which is assumed to act along the blade element and which will be equal to μP .

The thrust is the sum of the components of these forces at right angles to the plane of rotation and the pressure in the direction of motion is the sum of the components in that direction:

$$\begin{aligned}\text{Thrust} &= P \cos \theta - \mu P \sin \theta \\ \text{Resistance} &= P \sin \theta + \mu P \cos \theta.\end{aligned}$$

The torque is measured by the product of the head-resistance and the radius and, since it is directly proportional to the horsepower it follows that

$$\frac{\text{Thrust}}{\text{Horsepower}} \propto \frac{P \cos \theta - \mu P \sin \theta}{R (P \sin \theta + \mu P \cos \theta)}.$$

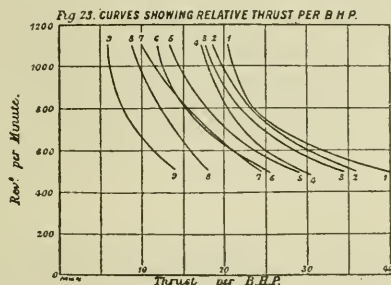
Dividing by P and \cos

$$\frac{\text{Thrust}}{\text{Horsepower}} \propto \frac{1 - \mu \tan \theta}{\tan \theta + \mu} \cdot \frac{1}{R}.$$

The expression decreases with increasing values of θ showing that the thrust per horsepower tends to decrease as the pitch or angle of attack increases.

It can be shown by differentiation of the thrust formula that the maximum thrust is obtained when $\theta = 35$ degrees, approximately, assuming μ to be small enough to be neglected. The maximum horsepower, obviously, is required when $\theta = 90$ degrees. An inspection of the test results for propellers Nos. 5, 7 and 8 will show that the mean value of the pitch angles for the important parts of the blade is about 35 degrees, and these are the propellers that give the maximum total thrusts.

In addition to the measurement of the thrust and horsepower, some experiments were made to determine as closely as possible the direction taken by the air thrown off by the propeller. To do this a light framework or cage of $\frac{1}{8}$ -inch wire was constructed round the propeller, giving an all-round clearance of about 6 inches, and light pieces or streamers of silk thread



and ribbon were attached at suitable points. Considering the streamers across a diameter, it was found that they were strongly impelled outwards up to a point which corresponded to a distance of about 3 inches from the tip at which point the regularity of the flow was apparently much disturbed by eddy currents. Proceeding towards the tip these eddy currents gradually diminished and from the tip outwards and round the side of the propeller the streamers were drawn markedly inwards. There was also a tendency for the streamers to be inclined in the direction of rotation, indicating a certain amount of whirling action produced by the propellers.

At the back of the propeller the streamers were drawn in towards the propeller and the curious effect was observed that those streamers, for the last three inches of the blade and just beyond the tip were drawn downwards and pointed, roughly, to

a point corresponding with the point at which the outward flow ceased on the front of the propeller. This appeared to indicate that the last 3 inches of the tip had no effect as regards the thrust. It was also observed that the direction of the flow at the front was not horizontal but was inclined to the plane of rotation at angles which, apparently, had some relation with the pitch, being steeper towards the centre of the propeller where the blade has the greatest slope. Also the direction of the streamers placed on a circle was found to be towards a point which lay on the axis of rotation. Hence if a small element of length of the blade is considered, the air driven from it will move along a surface that can be compared to the surface of a cone whose apparent axis and apex are on the axis of rotation. The position of this apparent apex moved nearer to the propeller as the radius lessened and the angle at which the air was driven off became greater. It must be understood that there was a considerable amount of eddying and that the direction of the air, as indicated by the streamers, can only form an approximation to what actually occurred.

Bituminous Surfaces. (*Eng. Rec.*, lxii, 8.)—Bituminous surfaces should have less crown than macadam surfaces. While $\frac{3}{4}$ in. to the foot is customary for macadam roads, $\frac{3}{8}$ in. or less is desirable on bituminous surfaces. Experience shows that roads made by mixing or grouting tar in the top course need a surface sealing coat, preferably of asphalt, for automobile and horse traffic, as that is less slippery, has a better appearance, and shows indications of a longer life than a surface coating of tar.

Fluxes in the Brass Foundry. EDWIN S. SPERRY. (*Iron Age*, lxxxvi, 3.)—A carefully considered paper, which will repay perusal. His conclusions may be summarized thus: For aluminum use zinc chloride; for nickel, use three parts of lime to one part of fluorspar; for copper, for copper castings use potassium ferrocyanide, but it is preferable to use de-oxidants, such as silicon-copper, magnesium and phosphorus; for brass or bronze use sodium chloride (salt); for German silver, use sodium nitrate and black oxide of manganese, also sodium chloride; for washings, grindings, etc., use plaster of Paris (calcium sulphate). In each case cover with coarsely granulated, not powdered, charcoal to prevent oxidation.

AMERICAN PATENTS IN ENGLAND.

AN IMPORTANT DECISION IN ENGLISH PATENT LAW.

A CASE of considerable interest to American inventors holding English patents was decided in the British High Court of Chancery on July 29th, ult. Judging from the copious reports of the trial in the English photographic journals, the case is regarded as of unusual importance from every point of view. The action in question was that of the Graphic Arts Co., of Philadelphia, against Hunters Ltd., of London, for infringement of the English patent on the Acid-Blast etching process.

The phase of the matter which is of general interest is presented by the fact that the judgment dismissing the action with costs was rendered on the specific ground that one of the claims of the patent was considered to be too wide, the decision being thus based on an expressly stated legal technicality without regard to the question which was really at issue. The conclusion of the judgment, as rendered by Mr. Justice Neville and reported in full in the *Process Engravers' Monthly* for August, is as follows:

"I have been invited to read the whole of the first ten claims, as each claiming the whole of the invention described from different points of view, but the words will not, I think, allow of it. The claims appear to me to be addressed to different combinations of the various parts of the process. I am informed that, according to American law, the invalidity of one or more claims does not invalidate the rest. This may possibly explain the character of the claims. Be this as it may, I think Claim I is too wide and on this ground that the letters patent cannot be supported. The action must be dismissed with costs."

This is in sharp contrast with the principle laid down by the Courts of the United States in similar cases, as appears from a recent decision in an action for infringement of the Gathright Tabulator patent. The United States Circuit Court of Appeals for the Second District, Judges Lacombe, Townsend and Coxe, in sustaining this patent, declared:

"In construing the claims consideration should be given to

the character of the improvements and the change in the art which is attributable to them. . . . In short, we are constrained to say that to this inventor belongs the credit of constructing the first commercially successful tabulator. The changes introduced by him seem simple and obvious in the light of the present . . . but his device was an improvement of such vital nature that the art, when considered from a practical and commercial point of view, began with him. He converted a theory into a fact. His invention belongs to that large class which has ever been treated with liberality by the Courts, when the inventor by an apparently simple change, addition or transposition of parts, has converted imperfection into completeness."

The practice of the English Courts in this respect, as evinced in the judgment above cited, is to be carefully noted by all who have any interest in British patents. W. J. WILLIAMS.

Use of Ferrotitanium in Bessemer Rails. P. H. DUDLEY. (*J. Ind. Eng. Chem.*, ii, 299.)—Ferrotitanium augments the toughness and ductility of the Bessemer rails containing 0.5 per cent. carbon and 0.096 per cent. phosphorus, which were designed for the N. Y. Central lines. The first severe tests were very satisfactory, and these results have now been further verified by two winters' service. While the plain Bessemer rails, in a 6-inch, 100-lb. section, had developed a number of fractures, those containing ferrotitanium, under the same experimental conditions passed through the unusually severe winter of 1909 without a single failure. The use of ferrotitanium improved the setting of the ingots, and helped to purify the metal. Acting as a subsidiary deoxidizer, in addition to reducing a large percentage of iron oxides in the steel, the ferrotitanium also reduced a portion of the nitrogen, thus decreasing the brittleness and increasing the toughness of the metal. For the same carbon content the ductility averages higher and runs more uniformly for a large number of heats when ferrotitanium is used than with ordinary Bessemer steel. Plotting the elongation under the drop-test (2000 lbs. falling 20 ft.) and the ductility, has been found to be of great value in guiding rail manufacture for high-speed trains.

Decomposition of Thorium Sulphate by Water. BARRE. (*Comptes rend.*, cli, 70.)—On heating thorium sulphate solution it gradually splits up into a fibrous mass of basic sulphate and free acid, decomposition beginning about 55°C. The basic salt slowly changes into a second, very crystalline basic sulphate. The first salt is obtained when thorium sulphate is added to sufficient water to ensure complete decomposition.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, September 21, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 21, 1910.

MR. JAMES CHRISTIE *in the Chair.*

Present, 155 members and visitors.

Additions to membership since last report,—11.

The paper of the evening on the Moore Light was read by Mr. D. McFarlan Moore of Newark, N. J.

The speaker gave a brief résumé of the early experiments with vacuum tubes, referring especially to the work of Hawksby, Geissler, Crookes, and others. He described the early investigations in connection with the system of vacuum-tube lighting bearing his name and outlined the various stages of development until it has reached its present state of usefulness. The subject was illustrated by means of lantern slides and by lamps in operation. The value of the white light as an aid to color matching was shown by a number of experiments.

The Chairman extended the thanks of the meeting to the speaker and the paper was referred to the Committee on Publications. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Proceedings of the Stated Meeting, held Wednesday, September 7, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Sept. 7, 1910.

MR. THOMAS SPENCER *in the Chair.*

In the absence of a quorum, reports for final action were not presented.

For first reading:

(No. 2480) Reeves Variable Speed Transmission.

(No. 2484) Jacker Weldless Chain Machine (Advisory, Adopted).

R. B. OWENS,
Secretary.

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

Changes of Address.

- MR. WM. F. SELLERS, Edge Moor, Del.
MR. E. H. SANBORN, 11th Floor, Arcade Bldg., Phila.
HIRAM HIXON, 509 Seventeenth St., Ocean City, N. J.
MR. JOSEPH J. O'BRIEN, 3471 Holmead Place, N. W., Washington, D. C.
MR. W. C. RUMFORD, care Wm. H. Horstmann Co., 5th & Cherry Sts., Phila.
MR. GEORGE VAUX, JR., 1606 Morris Bldg., 1421 Chestnut St., Phila.
MR. C. S. BRADLEY, 41 Park Row, New York City, N. Y.
MR. JOHN E. NETHERY, 813 Corinthian Ave., Phila.
MR. EDWARD G. BUDD, 502 Westview St., Germantown, Phila.

NECROLOGY.

Genth, Prof. Frederick Augustus, Jr.—The life work of a brilliant and widely known chemist, Prof. F. A. Genth, Jr., terminated on September 2. He died at his home in Lansdowne after a three months' illness in his fifty-seventh year. In his early career Prof. Genth enjoyed the rare advantage of access to the laboratory founded by his father to which he eventually fell heir, maintaining it until his last illness. His activities were of a distinctly two-fold type. On the one hand, he was prominently identified with commercial and legal chemistry; and on the other, he attained eminence as a teacher.

In 1876 and again in 1878 he received degrees from the University of Pennsylvania. He profited greatly in scientific knowledge while an aide to that most famous scientist and teacher—Lord Kelvin—and also to Dr. Joseph Henry of the Smithsonian Institution. From 1881 to 1889 he was assistant professor of chemistry at the University of Pennsylvania. He became a special lecturer in chemical jurisprudence in 1907 at the Medico-Chirurgical College which post he held a year, when he was promoted to the position of professor of mineralogy and assaying.

Professor Genth was a member of a number of foreign and American societies. Among the latter, the American Philosophical Society, the American Chemical Society and the Franklin Institute of which he was a member since 1874.

Hartman, John Markley, was born in Chester County, Pennsylvania, September, 1840, and died at his home in Mt. Airy, Philadelphia, September 4

1910. Mr. Hartman entered the works of I. P. Morris & Co. of Philadelphia as an apprentice at the age of seventeen, serving as machinist and mechanical draughtsman. Shortly after the completion of his apprenticeship, he joined with Lewis Taws in the brass foundry business, which developed into an establishment for the production of blast-furnace fittings and supplies.

Mr. Hartman devoted his attention largely to blast-furnace design, becoming an authority in this industry. He bore an important part in the development of the modern blast-furnace during the past forty years. Mr. Hartman was a member of the Institute for nearly fifty years and of the Committee on Science and the Arts for fourteen years.

Hyzer, John W., who was for many years a valuable member of the Institute, died on the 23d of August at Wildwood, N. J., where he was spending the summer with his family, at the advanced age of ninety-two years. His home was in this city at 1308 North Tenth Street.

Mr. Hyzer was born at Manheim, Pa., March 23, 1818, and attended school in this city. In 1839 he engaged in the iron business in Smyrna, Del. In 1848 he came to this city where he established a fire brick and floor tile manufacturing plant, with a cousin, under the firm name of Hyzer & Llewellyn, at 952 North Ninth Street.

LIBRARY NOTES.

Purchases.

BAUER and ROBERTSON.—"Marine Boilers."

BÖTTCHER and TOLHAUSEN.—"Cranes—Their Construction, Mechanical Equipment, and Working."

BOYCOTT, C. W. M.—"Compressed-Air Work and Diving."

DAVIDGE, H. T.—"Optical Instruments Simply Explained."

ERSKINE-MURRAY, J.—"Handbook of Wireless Telegraphy." Ed. 2.

GOOLD, JOSEPH, and others.—"Harmonic Vibrations and Vibration Figures."

GROTH, L. A.—"Welding and Cutting Metals by Aid of Gases or Electricity."

HASLAM, ARTHUR P.—"Electricity in Factories and Workshops."

HEDGES, KILLINGWORTH.—"Modern Lightning Conductors." Ed. 2.

HORNER, JOS. G.—"Modern Milling Machines, Their Design, Construction, and Working."

KING, A. G.—"Practical Steam and Hot Water Heating and Ventilation."

LUNGE, ERNEST.—"Compulsory Working and Revocation of Patents."

LUPTON, PARR and PERKIN.—"Electricity as Applies to Mining." Ed. 2.

SMITH, T. ROGER.—"Acoustics in Relation to Architecture and Building."

THORPE, T. E.—"Life and Work of Joseph Priestley."

WALLIS-TAYLOR, A. J.—"Motor Vehicles for Business Purposes."

WALLIS-TAYLOR, A. J.—"Refrigeration, Cold Storage, and Ice Making." Ed. 2.

WATT and PHILIP.—"Electroplating and Electrorefining." Ill.

WHEELER, CAPT. OWEN.—"Modern Telephotography."

Gifts.

- American Society of Civil Engineers, Transactions, vol. 68. New York, 1910. (From the Society.)
- Western Australia Geological Survey, Bulletin No. 33. Perth, 1909. (From the Survey.)
- Canada Year-Book, 1909. Ottawa, 1910. (From the Census and Statistics Office.)
- U. S. Commissioner of Patents Report, 1909. Washington, 1910. (From the Patent Office.)
- Institution of Civil Engineers, Transactions, vol. 180. List of Members, 1910. London, 1910. (From the Institution.)
- Lexikon der Papier-Industrie. Deutsch, Englisch, Französisch. Bearbeitet von L. Akesson, H. Everling und M. Flückiger. Herausgegeben von Lennart Akesson-Amrein. Zurich, 1905. (From Mr. L. Akesson.)
- Conservatoire National des Arts et Metiers, Catalogue Officiel des collections. Fascicule 4 and 6. Paris, 1908, 1910. (From the Conservatory.)
- Fornvannen. K. Vitterhets Historie och Antikivitetens Akademiens. Stockholm, 1909. (From the Academy.)
- Ontario Agricultural Societies. Tenth Annual Report. Toronto, 1910. (From the Agricultural Department.)
- Milwaukee, Wis., City Engineer. Annual Report. Milwaukee, 1909. (From City Engineer.)
- Bijdrage tot de Kennis der Constitutie van het Bixine. J. F. B. van Hasselt. Haarlem, 1910. (From the Technical High School, Delft.)
- The Railway Library, 1909. Compiled and edited by Slason Thompson. Chicago, 1910. (From the Compiler.)
- Iron and Steel Institute, Journal vol. 81. London, 1910. (From the Institute.)

Friction. F. CHARRON. (*Comptes rendus*, cl, 906.)—When two bodies slide, one over the other, there is generally a mutual tearing out of particles from each surface, which renders the phenomenon complex. In the case of pure friction, without any tearing out of particles, as the relative velocity of the two surfaces increases, the coefficient of friction decreases, and becomes zero for a particular velocity, the *critical* velocity. This diminution of friction is due to a layer of air, which is interposed more or less between the two surfaces for velocities less than the critical velocity and which separates them altogether for velocities equal to or greater than, the critical velocity. Experiments are given with copper, brass and graphite sliding over a plane glass plate, which rotated in its own plane round a vertical axis. When the apparatus was set up in an air-tight case, notable variations of the frictional force were found when the pressure was reduced to 2 or 3 c.m. of mercury. When the pressure was reduced to 1mm. of mercury, it was found that the coefficient of friction was sensibly independent of the velocity, thus confirming the conclusion as to the effect of the layer of air.

BOOK NOTICES

ENGINEERING CHEMISTRY. A manual of quantitative chemical analysis for the use of students, chemists and engineers. Fourth Edition. By Thomas B. Stillman, M.Sc., Ph.D., late Professor of Engineering Chemistry in the Stevens Institute of Technology. 744 pages, 174 illustrations. Easton, Pa., Chemical Publishing Co., 1910.

The major portion of this work is devoted to quantitative methods of chemical analysis—gravimetric and volumetric—of those materials which are closely connected with the science of engineering. Among the topics discussed are the modes of analysis of coal and coke, various metals, ores and alloys, asphalt, paints, cement. Gas analysis is discussed in respect to its application to the analysis of chimney, fuel and illuminating gases. A discussion of calorimetry, photometry and pyrometry is included in the work. Among the other subjects, to which chapters are devoted, may be mentioned acetylene, the determining of blast-furnace charges, feed water heaters and fuel economizers. The specifications of government offices and of corporations for such materials as coal, tin and terne plate, lubricating and burning oils, paints, soap and acids have been inserted in this edition. Various tables of properties and conversion tables are appended. References to original articles are freely given throughout the work. The illustrations of apparatus are excellent. H.

ALLEN'S COMMERCIAL ORGANIC ANALYSIS. Volume II, Fixed Oils, Fats and Waxes, Special Characters and Methods, Butter-fat, Lard, Linseed Oil, Higher Fatty Acids, Soap, Glycerol, Cholesterols, Wool-fat, Cloth Oils. Fourth Edition, edited by Henry Leffmann, M.A., M.D., and W. A. Davis, B.Sc., A.C.G.I. Philadelphia, P. Blakiston's Son & Co., 1910. Price \$5.00 net.

C. Ainsworth Mitchell has written the chapter upon the fixed oils, fats and waxes, including their extraction and purification, the determination of their chemical and physical constants, their classification, the detection of foreign matters and the identification of fats and fixed oils. He has also contributed a chapter upon lard. The special characters and methods of examination of the various fats, oils, and waxes are discussed by Leonard Archbutt. The article upon butter, butter-fat, and butter substitutes is the work of Cecil Revis and E. R. Bolton. C. A. Klein has prepared the chapter upon linseed oil, boiled linseed oil and blown oils. The higher fatty acids are discussed by W. Robertson, glycerol by W. A. Davis and cholesterol and phytosterol by John Addyman Gardner. The discussion of commercial soaps and their assay is from the pen of Henry Leffmann. Augustus H. Gill is the author of the chapter upon wool fat, suint, degreas and cloth oils. Throughout the entire book, references to the original literature are given in abundance. This work will be of value not only to the technical chemist, but also to the student and the research worker. H.

CURRENT TOPICS

Colloidal Solutions of Metallic Arsenic. LECOQ. (*Comptes rendus*, cl, 700.)—Red-brown colloidal solutions of arsenic were obtained by electrolyzing an alkaline solution using metallic As as anode, and by electro-reduction of arsenious acid using a Pt anode and Hg cathode. The addition of gum or of glycerol greatly increased the stability of the colloids. Precipitates were less readily formed in the presence of electrolytes than with other metallic colloids, a strong acid being necessary for rapid precipitation. Oxidation was rapid only in alkaline solutions.

Size of Particles Projected by a Kathode. L. HOULLEVIGUE. (*Comptes rendus*, cl, 1237.)—Experimenting with silver kathodes and collecting the projected silver on a strip of glass connected with a Wheatstone-bridge, thereby enabling the change in resistance to be measured, the size of the projected particles is found to be about $22\text{--}26\mu\mu$, which is of the same order of magnitude as the size of Bredig's colloidal silver, and he concludes that the particles projected from a kathode are not essentially different from the granules of colloidal metals.

Radio-activity of Potassium. J. ELSTER and H. GEITEL. (*Phys. Zeitschr.*, xi, 275.)—Potassium salts exhibit a slight radio-activity, as other investigators have shown. With the object of separating a more active substance, which might possibly occur in potassium, different salts were subjected to chemical processes, or their solutions electrolyzed. All these experiments led to negative results, showing that the activity of potassium must be ascribed to the metal itself. Special experiments were made to ascertain whether there is any emanation from potassium salts. The results were negative.

Aquadag as a Cutting Compound. (*Iron Age*, lxxxvi, 3.)—A large number of cold-rolled steel rods, with an average diameter of about 1 inch were being cut off in a lathe. When using an ordinary soap cutting-compound the cutting-off tool would make an average of 60 cuts with one sharpening, but when a small amount of deflocculated graphite was mixed with the cutting compound, the tool did not "dull" so rapidly and made 980 cuts with one sharpening. In a second trial the tool not only did about 16 times the work, but also the ends were smoother and the work done better. In boring and reaming a large number of holes in bronze

bushings the addition of aquadag to the cutting-compound enabled them to bore a hole the full size of the reamer, with a considerable reduction in the horsepower consumed.

The Rationale of Dried Blast. JOS. W. RICHARDS. (*Iron Age*, lxxxvi, 3.)—This paper treats of the benefits derived from drying the air-blast, which are, briefly: increased temperature for smelting; improvement in the ratio of CO_2 to CO through diminution of the carbon consumption in the smelting zone; increase of regularity of running, and quantity and uniformity of out-put; and general economy. This paper will well repay careful perusal and consideration.

Adulteration of Turpentine Oil with Copal Oil. W. VAUBEL. (*Zeit. Angew. Chemie*, xxiii, 1165.)—Turpentine oil to which copal oil has been added, does not dry satisfactorily, but leaves an acid, oily residue which renders it unfit for use in paint or varnish. It is dangerous to handle since copal oil may cause strong inflammation of the hands and eyes. Its presence in turpentine oil may be detected by the smell, the acid reaction and the bromine value of the residue left on evaporation.

Theory of the Cold Vulcanization of Rubber. F. W. HINRICHSSEN and E. KINDSCHER. (*Z. Chem. Ind. Kolloide*, 1910, 4.)—Definite quantities of a solution of Para rubber in benzene were treated for three weeks with measured quantities of a benzene solution of sulphur chloride, and then in an aliquot volume of the clear liquid, the residual sulphur chloride was determined. From the difference of the quantity of sulphur chloride taken and that remaining at the end of the experiment, the vulcanization coefficient was calculated. Results show that for a given quantity of rubber, the amount of sulphur chloride absorbed is approximately constant, and independent of the excess of sulphur chloride used. Hence vulcanized rubber is regarded as a definite chemical compound of the formula $(\text{C}_{10}\text{H}_{16})_2\text{S}_2\text{Cl}_2$.

Action of Pure Air and Water on Iron and Steel. J. A. N. FRIEND. (*Chem. Soc. Proc.*, xxvi, 179.)—A hollow cylinder of iron or steel closed at one end is supported in a flask, containing potassium hydroxide solution to absorb the carbon dioxide in the air, in such a way that cold water can circulate through the cylinder and connecting tubes. The flask is placed in a water-bath at 100°C ., and a current of cold water passed through the cylinder. Water vapor condenses on the outside of the cylinder and drips off, slowly washing it free from alkali. If the iron is pure it remains quite bright, thus proving that pure water and pure air combined have no action on pure iron.

Aluminum-Silver Alloys. W. BRONIEWSKI. (*Comptes rendus*, cl, 1754.)—The properties determined were (1) electrical conductivity; (2) the temperature coefficient of electrical resistance between 0° and 100° C.; (3) the thermo-electric power with respect to lead at 0° C.; (4) the variation of the thermo-electric power with the temperature and (5) the solution potential in ammonium chloride solution, with respect to a carbon electrode depolarized by manganese dioxide. The results show the production of two compounds, Al_2Ag_3 and AlAg_2 . The alloys are hard and resist external influences, and do not show the brittle zone characteristic of most alloys of definite molecular composition. The author is surprised that these alloys are not used industrially.

Tantalum Sulphide. H. BILTZ and C. KIRCHER. (*Ber.*, xliii, 1636.)—Hydrogen sulphide and carbon bisulphide vapor, carried by means of hydrogen sulphide, were passed over tantalum pentoxide at various temperatures. There was no sensible reaction with hydrogen sulphide at any temperature. Carbon bi-sulphide begins to react at 650° C. and reaction is complete above 900° C., and pure tantalum sulphide, with the formula TaS_2 , is obtained. This is stable at $+1300^{\circ}$ C. and at 1200° C. begins to be transformed into crystals, probably by sublimation. It readily absorbs traces of moisture, which it obstinately retains.

Sulphur Chloride and Thionyl Chloride. A. BESSON and L. FOURNIER. (*Comptes rendus*, cl, 1752.)—Sulphur monochloride mixed with hydrogen was completely decomposed by the electrical discharge, yielding sulphur and hydrochloric acid. Sulphur monochloride was reduced by hydrogen alone, with formation of sulphur, without the electrical discharge. By the action of heat even as low as the boiling point and more markedly at 170° to 180° C., sulphur monochloride was decomposed into sulphur di-chloride and sulphur. On exposing a mixture of thionyl chloride and hydrogen to the electrical discharge, sulphur monochloride, sulphur, sulphur dioxide, and hydrochloric acid were detected in the products of reaction. Sulphur dioxide and sulphur monochloride, when exposed to the electrical discharge yielded thionyl chloride, a little sulphuryl chloride, and sulphur. Under the influence of heat, sulphur dioxide and sulphur monochloride yielded thionyl chloride and sulphur.

Underground Leaks. (*Eng. Rec.*, lxii, 7.)—The Water Department of Washington, D. C., are said to have saved more than 6 million gallons per day or one-tenth of the daily consumption, from underground leaks discovered and stopped by the pitometer division. Most of this waste was due to defective service pipes leading into residences and business houses.



The JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

NOVEMBER, 1910

No. 5

SOME RECENT PROBLEMS IN STORAGE BATTERY ENGINEERING.

BY

MR. JOSEPH APPLETON,

Consulting Engineer of the Electric Storage Battery Company of Philadelphia.

(Presented at the meeting of the Electrical Section, held Thursday, October 6th, 1910.)

[The use of the storage battery in modern electric generating plants is given consideration in this paper. Mention is made of its application in various power plants and results of efficiency are presented.]

In presenting this paper to-night, my object has been to touch upon some of the most important developments which have recently been made in storage battery application and engineering.

The wonderful increase in the use of electrical energy for industrial purposes has developed the centralization of the generating station (on account of the increased capacity necessary), the distribution over large areas being effected by means of high tension lines and substations.

The increase in the size of the generating station necessarily alters the method of storage battery application to such systems. They are no longer used to any extent to even up the load on the generating machinery, but are used for emergency or "stand-by"

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

service in substations and to carry peaks of short duration. In systems generating current at one or more stations and distributing it over wide areas there must of necessity be many chances of interruption of service due in the majority of cases to causes outside the control of the Company operating the system. By this I mean accidents to transmission lines through excavations, building operations, etc. These interruptions are usually of short duration but may affect the whole system.

The New York Edison Co., one of the early pioneers in storage battery application, realized the value of storage batteries for this purpose on their system and attacked the problem in a radical and novel way.

A little over two years ago they asked me to meet their engineers and discuss the problem of furnishing storage batteries for emergency or "stand-by" service having the following characteristics:

Maximum output of energy for short periods.

Minimum first cost and up-keep.

Minimum space requirements and weight.

Last, but most important from the manufacturing and commercial side, these batteries need only have a life of about three hundred discharges, as the estimated number of discharges per annum in this service would not exceed twenty or thirty.

The company with which I am connected undertook to solve this problem with the result that in 1908 we installed for the New York Edison Co. in their Thirty-ninth St. Substation a battery of this type.

The plates used were a development of the well-known Exide plate and I will give you some comparative figures between this type of battery and the standard Manchester plate which the Edison Companies have been using for the past twelve years.

Fig. 1 exhibits the results taken from a Standard Manchester cell containing sixty-nine H-plates and the same cell filled with Exide H-plates. The Exide plates being thinner, 111 can be installed in a tank of the 69 H-Manchester type.

Summarizing these figures it will be seen that the new type of plate has a much greater output at high rates, and will maintain same for a longer period of time with a higher terminal voltage. Take, for example, the discharge at four times the hour rate. The Exide plates give nearly twice the output of the old plate.

for double the time, and with a higher terminal voltage. For the same space occupied, with only 15 per cent. increase in weight, the output of the new plate will vary from about two to four times that of the old plate, according to the rate of discharge taken as a basis of comparison.

The question of floor space is a most important one in sub-station equipment, and a reduction in battery space required means a saving both in real estate and cost of building. Bat-

FIG. 1.

MANCHESTER

WEIGHT _ _ _ _ _ 5800 POUNDS PER CELL COMPLETE.

4850 Amp. for 1 Hour down to 1.6 Volts per Cell.

9700	"	"	15 Min.	"	"	1.4	"	"	"
14500	"	"	6.5 "	"	"	1.2	"	"	"
19400	"	"	3 "	"	"	1	"	"	"

EXIDE

WEIGHT _ _ _ _ _ 6600 POUNDS PER CELL COMPLETE.

9166 Amp. for 1 Hour down to 1.64 Volts per Cell.

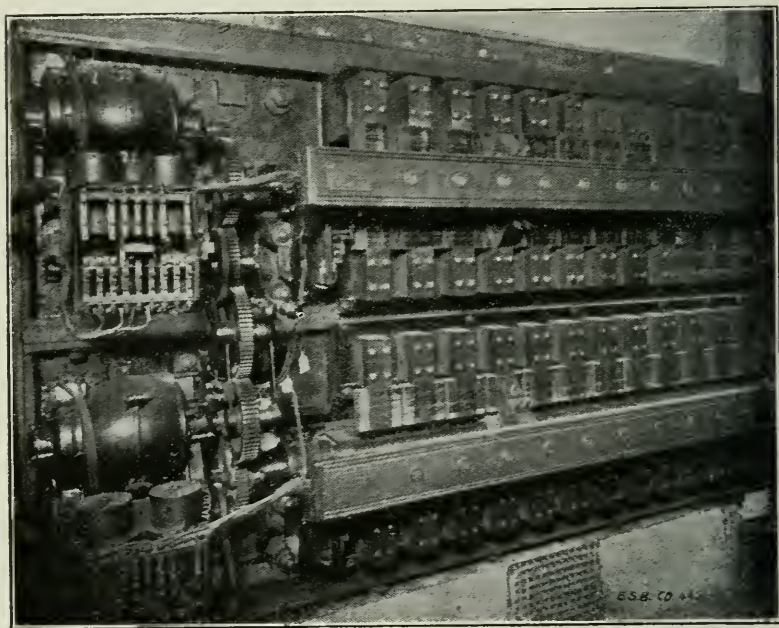
18333	"	"	21 Min.	"	"	1.48	"	"	"
27500	"	"	10 "	"	"	1.32	"	"	"
36666	"	"	6 "	"	"	1.16	"	"	"

teries used for this emergency service are not called upon to discharge as many kilowatt-hours per annum as in the former service, and consequently will remain in operation for a much longer time without needing renewals. This makes a material difference in the cost of maintenance. This type of cell will, I believe, open up a more extensive field for storage batteries in connection with large distributing systems of electrical energy, on account of the greater output obtainable, which places the cost per kilowatt upon a different basis, and makes a most attractive proposition. The use of this battery is not necessarily restricted

to large systems, but will give equally satisfactory results in the case of smaller plants.

The results obtained from the first battery of this type installed for the New York Edison Co. were so satisfactory that since that battery was installed, ten large batteries have been purchased by the larger Edison Companies. One battery in particular I would like to say a few words about on account of its size. It is installed in the Sixteenth Street Substation of the

FIG. 2.



New York Edison Co. It consists of 150 cells, each containing 131 H-Exide plates. The output at various rates is as follows:

- 10790 amperes for 1 hour.
- 21580 amperes for 21 minutes.
- 32370 amperes for 10 minutes.
- 43160 amperes for 6 minutes.

The use of the emergency or "stand-by" batteries with these high rates of discharge made it necessary to develop end-cell switches which could carry such enormous currents and enable

additional cells to be cut in during the discharge as the voltage of the cells dropped.

Fig. 2 shows two of the four end-cell switches installed with the battery I just referred to for the New York Edison Co. They have twelve points to each switch, seventeen end-cells being connected to them as follows:

- 9 points with one cell between each point.
- 3 points with three cells between each point.

FIG. 3.

BATTERIES ON EDISON SYSTEMS

KILOWATT HOUR CAPACITY AT 1 HOUR RATE

BOSTON-----	7016.44	9	BATTERIES
NEW YORK-----	32342.00	44	"
BROOKLYN-----	7174.00	11	"
PHILADELPHIA-----	2277.60	4	"
CHICAGO-----	24216.13	26	"
OTHER-----	41461.39	66	"
TOTAL-----	114488.00	160	"

This arrangement gives one cell per point regulation around the floating point so that the battery voltage can always be adjusted to the bus voltage.

These switches have a maximum capacity of 20,000 amperes for short periods, and can be operated from point to point while carrying that current.

Switches of similar type having a maximum capacity for short periods of 40,000 amperes are now being constructed.

Fig. 3 shows the battery capacity in use by the Edison Companies throughout the country. This table is calculated on the

one hour discharge rate capacity, and of course for shorter periods the output is increased.

Only a few of these batteries are the latest Exide type for emergency service, but figuring on the Manchester ratings, the capacity of these batteries for six minutes would be 343,464 kilowatts or the equivalent of 17,000,000 20-watt lamps.

Some figures compiled last spring show the following percentage of battery capacity (figured on the one hour discharge rate) to the maximum direct current peak loads of the following companies :

New York Edison	25 per cent.
Chicago Edison	48 per cent.
Brooklyn Edison	36 per cent.
Boston Edison	36 per cent.

Before leaving this part of our subject I would like to refer to a new field for storage batteries in connection with purchased power contracts.

The low cost of production of electrical energy, due to the greater capacity of generating stations, enables the consumer, in most cases, to purchase power cheaper than he can produce it, and the question of the relations between manufacturer and consumer has greatly increased in importance. Nearly every consumer will have different conditions both as to load and duration of time during which power is required, and the central station manager is confronted with the problem of marketing his energy so as to give the best net results from a financial stand-point.

Storage batteries must, and do, play a very important part in power contracts of this sort. It is not within the scope of this paper to consider the various forms of power rates or contracts, but I wish to point out the fact that the installation of a storage battery will often turn a customer with a poor load factor into one with a good load factor, to his gain and also to that of the central station. These situations are very numerous, each plant requiring individual investigation to ascertain the best arrangement to adopt to make the customer as profitable as possible, and moreover, they cover all kinds of service, both direct and alternating-current. The two principal methods of using storage batteries in connection with power contracts are as follows :

First.—To relieve the purchased power of frequent fluctuations, thereby improving the load factor and keeping down the maximum demand.

Second.—To carry peaks of short duration so that the same improvement of load factor and reduction in maximum demand may be effected.

In many cases that have come under the writer's notice, customers have peaks that exist for only a few months in the year, but by the use of a storage battery a better load factor for the entire year can be maintained. An interesting example of this application is found in the case of a large railway company in Chicago, purchasing power from the Commonwealth Edison Company, with which contract, on account of its important features, you may be familiar.

Probably the most interesting recent development from an engineering stand-point is the regulation by storage batteries of alternating-current generating plants and I will touch on two different applications along these lines.

1. Where generating plant is AC but load is DC , rotary converters or motor generators being used to transform the AC to DC .

2. Where generating plant is AC and load is principally AC with a small proportion of DC .

Illustrating the first application I will refer to the plant of the Otsego & Herkimer Railroad Company, New York. This Company operates an electric railway system in New York State extending from Oneonta to Mohawk, a distance of about 55 miles, with a three-mile spur to Cooperstown and about three miles of track for local service in Oneonta.

The power is generated at two different power houses, one a steam plant at Hartwick, and the other a water-power station on the Susquehanna River at Colliers.

Energy is transmitted from the Water-Power plant to the steam station at 13,000 volts, 3 phase 25 cycles, where it is connected in parallel with the steam station bus; from there it is transmitted over a 13,000 volt 3 phase line to the distant substations.

There are four substations, one at the steam power house, and three distant ones.

The substations are equipped with 300 k.w. 600 volt rotary converters.

The storage battery and auxiliary apparatus is installed at the steam power house and is so arranged as to regulate on both the water-power and the steam-power generating plants.

For controlling the charge and discharge of the battery a motor-driven booster is installed together with a motor-driven exciter controlled by a carbon regulator. This regulator is operated by an *A C* solenoid connected to the generator circuits in such a way as to respond to small variations of combined load on all of the units which are in operation at any time. The battery with its booster in series is connected directly across the 600 volt *D C* bus in parallel with the rotary converters which feed the railway circuit at that point. As stated above, however, the operation of the battery is so controlled as to regulate the total load on the system and fluctuations of this total load above or below the average whether originating at the power house substation or at one or more of the others, are handled by the battery which charges from, or discharges into, the *D C* bus at the power house substation to effect this result. Thus, if a heavy increase of load should occur at one of the remote substations the battery will relieve the *D C* load at the substation where it is located to a sufficient extent to compensate for the increase elsewhere and hold the total load on the system constant. If the increase in load is sufficient the battery may take the entire *D C* load of the converters at the power house and upon further increase discharge back through these into the *A C* circuits.

Fig. 4 is a load diagram showing the results obtained by the battery operation. The heavy line represents the total generator load while the light line is the total combined load of all the substations. The difference between these two lines showing the battery charge and discharge.

To illustrate the second application of *A C* regulation, I will refer to the plant of the U. S. Steel Co. at Gary, Indiana.

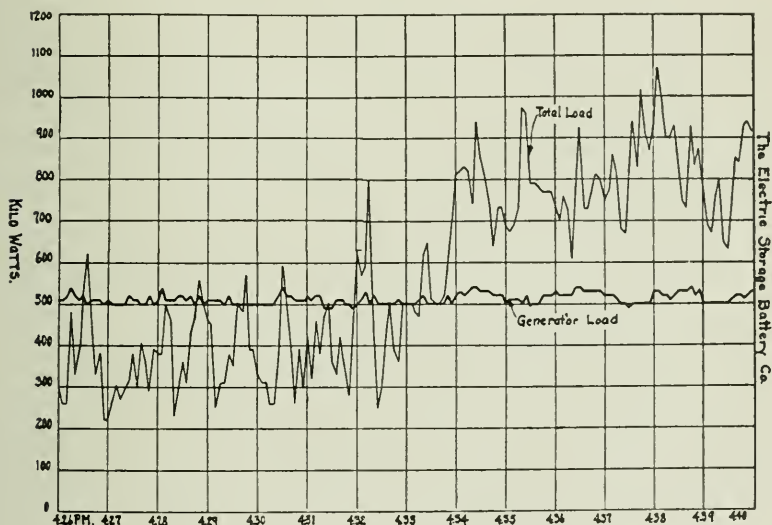
This plant is so unique and interesting that at the risk of repeating to some of those present what they may already know about it, I venture to give some figures illustrating its enormous size and modern features. I was fortunate enough to be closely connected with the engineering details of the power and distribut-

ing plant, and cannot but admire the courage exhibited by those designing the outfit.

The opportunity was presented at Gary to design from the ground up a complete steel plant of a magnitude greater than before attempted and without restrictions imposed by consideration of existing equipment and buildings.

The site of the plant is at the extreme southern end of Lake Michigan, 26 miles from Chicago. It consists of about 10,000 acres which were absolutely uninhabited and undeveloped. The

FIG. 4.



advantages found here were lake transportation, cheap land, and splendid railroad facilities.

The governing feature in the design was economy of operation and to this end the arrangement was so planned as to get the best possible facilities for transporting the material during the various stages of manufacture throughout the entire works. The electric motors were adopted as a source of power wherever they could be applied, namely, to drive ore unloaders, ore bridges, car dumpers, bin-filling cars, scale larries, blast-furnace skips, hot-metal mixers, electric cranes of all sizes and description, open-hearth charging tables, ingot buggies, gas producers, main rolls

of mills, rolling tables, lifting tables, transfers, and a multitude of machines too numerous to mention here.

To add further to the economy, it was decided to use blast-furnace gas in gas engines for driving electric generators to furnish the electric power throughout the plant. The gas from eight blast-furnaces is used for the electric power station. These eight blast-furnaces producing 3600 tons of pig-iron for 24 hours will give a total of 22,450,000 cubic feet of gas per hour: 30 per cent., or 6,750,000 cubic feet, of this gas is used for treating stoves; 7.5 per cent., or 1,700,000 cubic feet, is used under the boilers to furnish steam for spare steam engines, pumps, and miscellaneous heating; 2.5 per cent., or 600,000 cubic feet, is necessary for operating the gas washers; 15 per cent., or 3,400,000 cubic feet is used by the blast-furnace blowing engines. The remaining 45 per cent., or 10,000,000 cubic feet per hour, is available for power purposes. If estimated at 90 B.T.U. per cubic feet and 10,000 B.T.U. per boiler horsepower, this gas is equal to 90,000,000 boiler h.p. in gas engines.

The electric power station, which on account of its size and to make the operation more reliable, is divided into two sections, contains 17 gas engines, each rated at 3000 h.p., driving fifteen 2000-kilowatt *A C* units and two 2000 *D C* units. There are also two 2000-kilowatt *A C* units driven by steam turbines, all being capable of standing 50 per cent. over-load. It will be seen that only about 50 per cent. of the available gas as calculated will be used in this station, thereby making full allowance for furnaces out of blast and for shortage of gas due to troubles that are liable to occur to furnaces during operation.

The gas engines are horizontal twin-tandem double-acting, running at $83\frac{1}{3}$ revolutions per minute. The cylinders are 44 inches in diameter with 54-inch stroke. The floor space occupied by each engine and generator is 74×39 feet with an approximate weight of 1,700,000 pounds. The steam turbines were installed primarily for use in the construction of the plant and to furnish power for starting up.

The switchboard in this plant is most interesting and contains many special features. Each piece of generating and distributing apparatus in the power station is under the control of the operators stationed at the bench-board in the gallery, re-

mote control apparatus being used even down to the smallest capacities.

The enormous capacity of this plant is perhaps illustrated by the rail mill which has a capacity of 4000 tons of finished rails per 24 hours. It is not only the largest but also the only electrically driven mill in the world, rolling rails direct from the ingot without re-heating. The main rolls of the mill are driven by five induction motors having a combined capacity of 22,000 h.p., made up of three 6000-h.p. and two 2000-h.p. units. Besides these there are the auxiliary motors for operating the tables, transfers, hot saws, etc.

Fig. 5 shows the combined load of the rail mill which it will be noted fluctuates from 4400 to 19,000 h.p., with an average of 12,025 h.p.

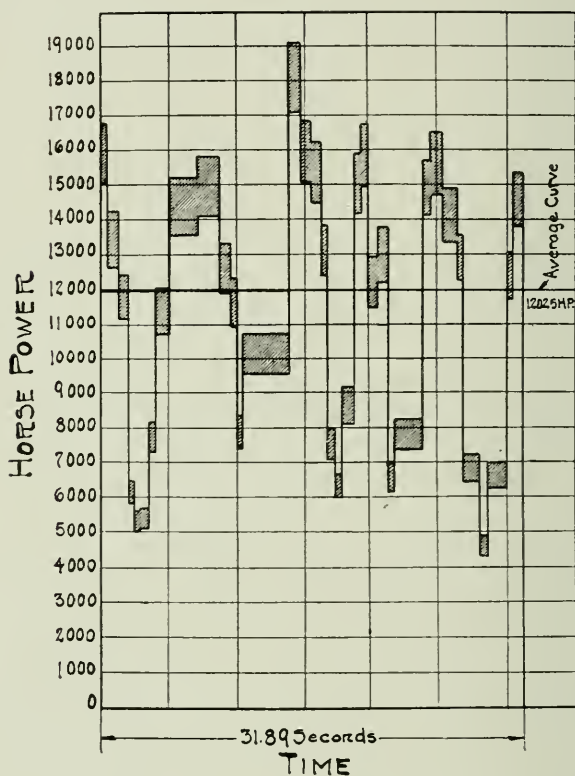
The brief description of this plant given above will readily enable an engineer to understand the extremely fluctuating character of the load and also the magnitude of the fluctuations.

A storage-battery equipment was installed principally to minimize the fluctuations of the load on the generating station and this equipment is unique in many ways. It has been found since the plant has been in operation that many advantages are derived from the battery which were not anticipated when the plant was designed. It will be noted that about 90 per cent. of the generating plant is $A C$ and the storage battery equipment is designed to take care of both $A C$ and $D C$ fluctuation. The battery consists of two series of chloride accumulators, each series containing 125 cells. Each cell contains 73 Type R plates. The capacity of each series is 4320 amperes at the one hour rate, or 8640 amperes at the usual regulating rate. This latter writing is more or less arbitrary, the cells being capable of discharging momentarily at much higher rates under emergency conditions should the demand arise. Discharges as high as 25,000 amperes have been taken from this battery.

The regulation of the $A C$ load and the emergency service in connection with same is the principal function of the battery as well as the most interesting on account of the methods involved. The $A C$ service is accomplished by means of two split-pole convertors which are connected between the battery and the $A C$ bus, each convertor having a continuous rating of 6800 amperes direct current in either direction, with a voltage range from 225 to 275

volts at the direct-current brushes. The momentary over-load ratings are 10,000 amperes output as a true convertor at 300 volts, or 14,000 amperes input as an inverted convertor at 200 volts. The alternating voltage at the collectorings remaining constant throughout these ranges of direct voltage. The direct current terminals of these convertors are connected directly across

FIG. 5.



the battery without the interposition of any booster, and the variation of direct voltage required to cause the battery to charge and discharge is brought about by varying the distribution of field flux over the pole face. The convertors for this installation were originally designed to operate as three-part pole machines, each pole being divided into three sections, each section being provided with separate shunt windings. In this type of machine in order

to reduce the direct voltage without changing the alternating voltage the field-strength of the outer sections of each pole is reduced, while the field-strength of the middle section is increased. This change in the distribution of the field flux producing a variation in the voltage ratio of conversion. The excitation for the main-pole sections is obtained from a 230-volt exciter bus and the windings on the auxiliary-pole sections are excited from a specially designed synchronous exciter.

The exciter in this installation is an eight-pole machine. The armature being provided with a four-pole winding and driven by a four-pole synchronous motor. There are eight brushes bearing on the commutator, four of these being the auxiliary brushes, which are short-circuited, while the other four are connected in pairs and constitute the main terminals of the machine.

For supplying alternating current to this exciter, a current transformer is connected in each phase of each of the main generators. These current transformers are connected to a set of common totalizing bus bars, which in turn are connected to the primaries of three totalizing current transformers. The secondary windings of the latter are connected to the collector rings of the exciter. This arrangement was made necessary owing to the fact that there is no point in the main *A C* bus bars of the station through which the entire output of the plant passes—the outgoing *A C* feeders being connected at various intermediate points between the points of connection of the main generators, so that there is no point in the bus bars where a single set of current transformers could be connected for regulating the total load.

Inasmuch as the main bus bars of the station are installed in duplicate, it was found necessary to duplicate the totalizing bus bars for the current transformers. The switching arrangements are such that any number of the main generators may be connected to one set of bus bars while others may be connected to the other set. The feeders may also be divided between the two sets. The split-pole convertors may be connected to either set of bus bars for regulating. The oil switches which connect the generators and the convertors to the bus bars are installed in duplicate, one set for each set of bus bars. The oil switches are provided with pallet switches, interlocked in such a way that when the convertor is connected to one set of main bus bars the totalizing current transformers are connected to the corresponding

totalizing current transformer bus bars. When any generator is connected to either set of bus bars, its current transformers are connected to the corresponding totalizing current transformer bus bars. The exciter therefore responds to the fluctuations of load on only those generators which are connected to the bus bars to which the split-pole converter is connected. The totalizing-current-transformer bus bars, which are not in use for regulating at any time, are automatically short-circuited.

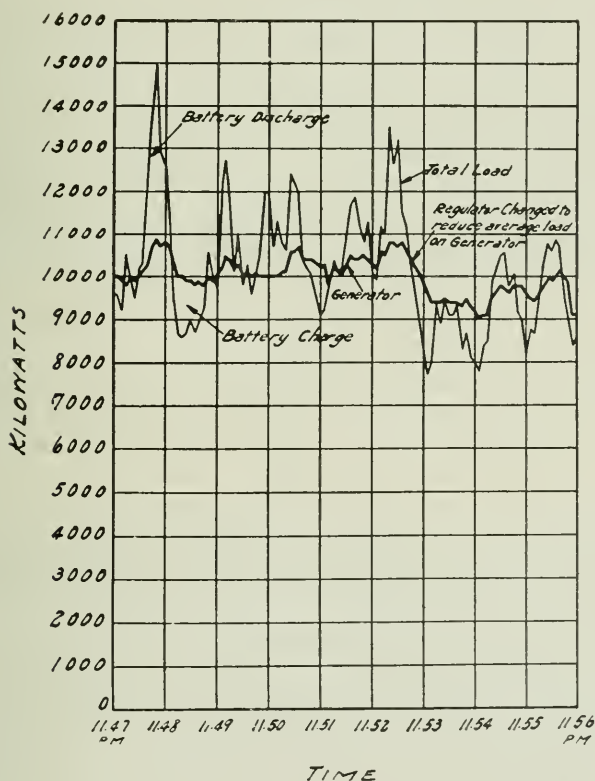
The battery is also arranged to regulate the fluctuations of load on the direct-current bus bars, but, as previously shown, the direct-current load is only a small portion of the total, is not extremely fluctuating and contains no features of special interest. This regulation is obtained by means of two direct-current boosters connected between the battery and direct-current bus; these can be operated singly or in parallel. The boosters are provided with carbon-regulator control in the usual manner, the carbon regulator being actuated by a soft-iron horseshoe magnet suspended over a section of the direct-current bus bar. The operation of these boosters in conjunction with the battery is like any other direct-current regulating plant, and is well known.

Fig. 6 shows the regulation obtained by the battery on the *A C* bus bars. In this diagram the heavy line represents the total load on the alternators, whose load is being regulated, while the light line is the total load on the station, the difference between the two lines showing the discharge or charge of the battery. The curves are plotted in kilowatts, the alternator load being taken by a recording wattmeter connected in the circuit of the totalizing-current transformers and calibrated to suit the ratio of same, while the battery output was calculated from readings of the current and voltage taken every five seconds from the ammeter and voltmeter. It will be noted that during the first six minutes shown on the curve the load on the alternator is held between 9800 and 10,900 k.w., and during the latter portion of the curve the average load was changed and was held between 9000 and 10,020 k.w. During the entire period of the curve the maximum variation of the load on the station was from 7700 to 15,000 k.w., a change of 7300 k.w. During the period of this curve the battery output varied from 4100 k.w. discharge to 1800 k.w. charge.

The practical commercial results obtained from the storage battery in actual operation have been extremely satisfactory and

gratifying to all concerned, and the following features have been most clearly demonstrated: Regulation of both *A C* and *D C* loads making the parallel operation of large gas engine driven alternators under fluctuating load conditions entirely practicable. An interesting point in connection with this feature is the marked effect of the battery regulation on the gas-engine driven alter-

FIG. 6.



nators located in the South Chicago plant of the Illinois Steel Co., some 11 miles away from Gary, but which is connected to it in parallel by a three-phase tie line. When for any reason the battery at Gary is disconnected or the tie line between the power stations is opened, a most decided difference is noticed in the operation of the South Chicago engines. One of the most

obvious practical commercial results of the battery regulations is the increased speed at which the large rail mill is operated. If for any reason the battery is disconnected, the output of the rail mill is materially reduced. The emergency feature is very valuable and enables the most important portion of the load to be carried uninterruptedly through times of interruption of service, due to line or other troubles which of necessity will occur in plants of such magnitude and covering such a wide area of distribution. The vital necessity for continuity of service in steel mills is well understood, and the effect of the battery in preventing costly delays and adding the safety feature, which cannot be estimated in dollars, undoubtedly warrants the investment for the battery, even if this were not largely offset by the saving in investment for additional generator capacity which the battery replaces. The results obtained at this plant indicate that the storage battery is an indispensable part of such an equipment.

This plant has been in operation about two years and plans are now under way for doubling the size of the power house and storage battery equipment.

In connection with the regulation of fluctuating loads by means of storage batteries there is one development I wish to mention to-night, as it shows the high state of perfection to which this class of work has been brought. It is a device to enable the storage battery equipment to take the quick fluctuations, relieving the generating machinery of them entirely but throwing slowly onto the generators fluctuations which are sustained for any length of time.

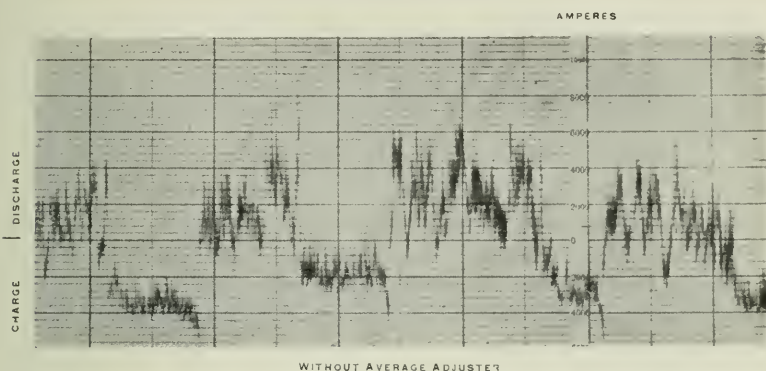
Heretofore the booster regulating systems have not been designed to differentiate between a rapid fluctuation and a slowly changing load; that is to say, if the regulator were set for a certain average load it would tend to hold the generators at that load regardless of the duration of the change in the outside demand; and the only method of altering the output of the generators was hand manipulation of the regulator. It has been found in a number of cases that the battery has not only had to take the fluctuations for which it was designed, but has also had to handle peaks of long duration on account of changes in load conditions which were not noted by the station operators.

The objections to this are twofold: First the station is not

running at its highest economy, and second, useless work is put upon the battery.

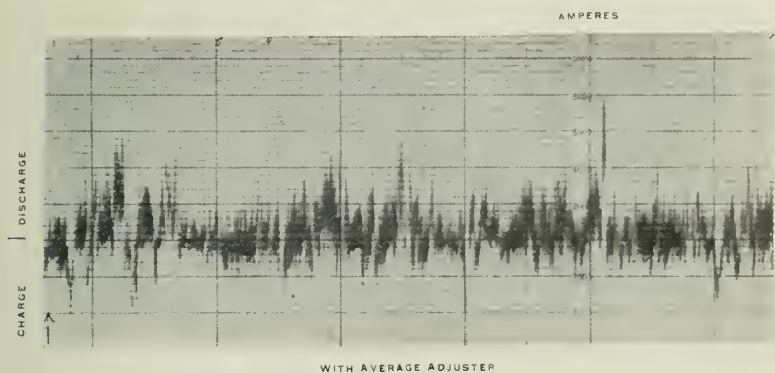
For these reasons there was developed an automatic device for changing the average load on the generators with sustained

FIG. 7.



changes in the demand. This device consists of a small motor actuating the booster regulator through reducing gear. The principle of its action is that on a discharge of the battery the

FIG. 8.



motor is operated so that it revolves in a direction slowly to raise the load on the generators. On a charge of the battery the motor runs in the opposite direction, thus slowly relieving the generators of load.

It is evident that a battery equipped with the average adjuster will still take the rapid fluctuations, but will not hold the generators to a fixed average, the sustained changes being gradually transferred from the battery to the machines.

To hold the generator load line below a fixed limit, a simple stop has been designed to open the adjuster circuit when the generator load reaches a predetermined point. The generators can thus be made to work up to any desired limit, the battery taking all the quick fluctuations and also the sustained peaks above that limit.

The accompanying diagrams, taken on a plant in actual service, illustrate clearly the action of the adjuster. Fig. 7 is a chart showing battery charge and discharge without the adjuster. Fig. 8 is a chart showing battery charge and discharge on the same system with the adjuster in operation. It will be noted that in Fig. 7, in addition to fluctuations, the peaks taken by the battery are considerable; while in Fig. 8 the battery takes the fluctuations, but does very little peak work.

The adjuster is of simple design, and it is believed that the improved economy of operation effected by it will make it an extremely valuable adjunct to battery installations operated in regulating service.

Control of Air in Buildings. (*Eng. Rec.*, lxii, 7.)—Although the necessity for pure air in buildings has long been recognized, outside air was supplied without any attempt at purification. It is now recognized that an efficient air supply involves the regulation of temperature, humidity and purity. In foundries, storage-battery plants, potteries and many other industries it is necessary to remove fumes or dust to protect the workmen. Aside from the hygienic aspect, the successful operation of certain manufacturing operations, such as textiles, gelatin products, photographic films, and confections is to a large extent dependent upon atmospheric conditions. In such places as coal-mines and flour mills the removal of dust is necessary to prevent explosions. In cities where the air is contaminated by dust and smoke, the air should be purified either by cloth filters or washers; the latter removing dust and floating matter and to a certain extent the soluble gases. In many cases the increased efficiency of employees more than offsets the cost of the ventilating plant.

THE PERMEABILITY OF PAINT FILMS.

BY

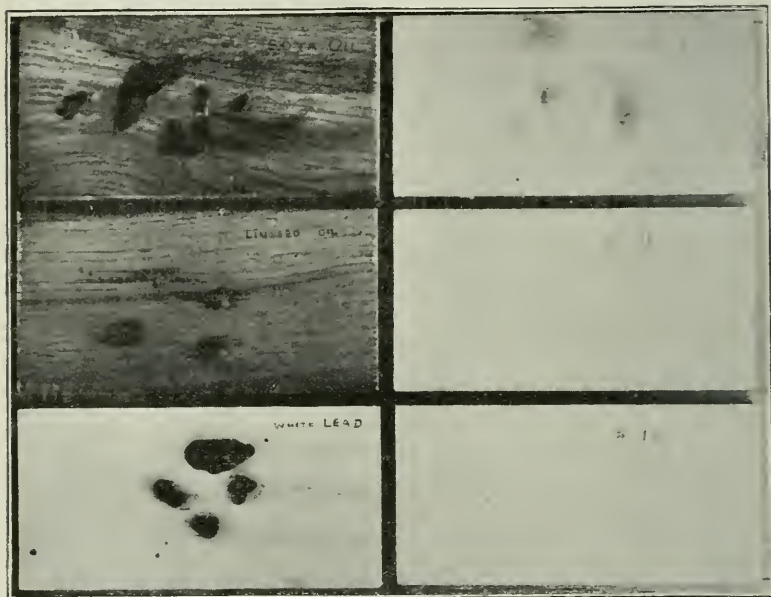
HENRY A. GARDNER.

THE writer some time ago made a series of tests to determine the water-excluding values of various combinations of painting pigments ground in pure linseed oil. White pine boards six inches long, four inches wide, and one inch thick were carefully prepared and numbered and given three coats of a white paint formula of the corresponding number. After drying, the boards were carefully weighed and immersed in a tub of water for three weeks. After removal, the surfaces of the boards were dried with blotting paper and the boards weighed. The gain in weight, corresponding to the amount of water penetrating through the pores of the wood, was observed. The boards were again immersed and at the end of two months the following results were obtained:

Formula No.		Grammes of water absorbed through paint
1	Soya Bean Oil	120
2	Linseed Oil	102
3	Calcium Sulphate	93
4	Barytes	88
5	Asbestine	74
6	Corroded White Lead	59
7	{ Basic Carb.—White Lead 25 per cent. }	58
	{ Basic Sulph.—White Lead 20 per cent. }	
	{ Zinc Oxide 25 per cent. }	
	{ Calcium Sulphate 25 per cent. }	
8	{ Calcium Carbonate 5 per cent. }	56
	{ Sublimed White Lead	
9	Zinc Oxide	56
10	{ Zinc Lead White 30 per cent. }	42
	{ Zinc Oxide 40 per cent. }	
	{ Basic Carb.—White Lead 20 per cent. }	
	{ Calcium Carbonate 10 per cent. }	
11	{ Basic Carb.—White Lead 50 per cent. }	42
	{ Zinc Oxide 50 per cent. }	
12	{ Basic Carb.—White Lead 38 per cent. }	38
	{ Zinc Oxide 48 per cent. }	
	{ Silica 14 per cent. }	

The test boards were then exposed, with their content of water, to the action of the sun's rays. Blistering of the painted surfaces took place in many cases, caused by the rapid withdrawal of the water and its consequent action on the paint film. The tests seem to indicate that a mixture of white lead and zinc oxide, with or without a small percentage of the inert pigments,

FIG. 1.



Photograph of painted boards treated with indicators showing the relative permeability of the different paints applied.

Top panel painted with Soya bean oil.
Middle panel painted with linseed oil. Bot-
tom panel painted with white lead in oil.

Top panel painted with No. 7 formula.
Middle panel painted with lead and zinc,
No. 11 formula. Bottom panel painted with
lead, zinc and silica, No. 12 formula.

is not as subject to the action of the water as the single pigment paints. In order, however, to corroborate these tests, it occurred to the writer to develop a more visible means of demonstrating the passage of moisture through paint films.

Another series of white pine boards were therefore soaked in a solution of iron sulphate for several hours. After removal, the surface of each board was dried and coated with one coat of the paints previously tested. After thorough drying for forty-eight

hours, there was placed on the surface of each board a few drops of a solution of potassium ferrocyanide. This solution has the effect of producing a blue coloration with iron sulphate, and in every case when it was placed on a paint of considerable porosity the solution penetrated through and formed a blue coloration beneath the paint. The results obtained on a few of the tests are shown herewith, and these results seem to corroborate the original tests referred to above (Fig. 1).

A series of sheets or films of paints were prepared by painting on glue-sized paper. Immersion of the painted paper in warm water allowed the removal of the paint films intact. These films were placed over a glass dialyzing cup, allowing the inner surface to sag so as to hold a small amount of dilute ammonium chloride solution. Distilled water was placed on the reverse side of the dialyzing apparatus and the test started. At the end of six days the distilled water in each test was examined and the following results obtained:

Test No. 1 (Corroded White Lead) allowed the passage of 0.003 Gm. ammonium chloride.

Test No. 2 (Corroded White Lead and Asbestine) allowed the passage of 0.002 Gm. ammonium chloride.

Test No. 3 (Corroded White Lead and Zinc Oxide) allowed the passage of 0.0003 Gm. ammonium chloride.

Tests were also made with dilute solutions of other salts such as ferric chloride, having a dilute solution of potassium sulphocyanide on the reverse side of the apparatus. In the latter case the formation of a pink color, characteristic upon the mingling of these solutions, was obtained in a few hours.

Earth Currents in Stockholm During the Transit of Halley's Comet. D. STENQUIST AND E. PETRI. (*Nature*, lxxxiv, 9.)—Observations were made at the Central Telegraph Station at Stockholm, of earth currents on two lines: Stockholm Göletorg (resistance 2940 ohms) and Sundsvall-Stockholm (resistance 2336 ohms). Measurements made from minute to minute from 0 hrs. 40 min. to 3h. 45 min. The measured currents were considerably above the normal for the time of day, but not so large as during a magnetic storm. The greatest disturbances occurred shortly before and after 2 A.M. when the p.d. east to west was +68.1 and that north to south was +56.6 millivolts per k.m.

Turbo-Electric Propulsion of Ships. H. C. LEAKE. (*Electrician*, lxxv, 19.)—The British Westinghouse Electric Co.'s system, invented by J. N. Bailey, comprises alternating-current, 3-phase, squirrel-cage motors, usually four in number, coupled direct to the propellers; each pair of motors is electrically connected, through reversing and isolating switches only, to a separately excited turbo-generator. Starting and speed regulation of the propellers is effected by starting, and by varying the revolutions, of the main turbines. For reversing at full speed these turbines are fitted with special steam brakes, which are applied until the frequency is sufficiently low to allow the reversing switches to be thrown over. The various operations are electrically controlled with alternative hand mechanism. Stress is laid on the great simplicity of the system.

Change of Resistance of Metals at Different Temperatures in a Magnetic Field. S. C. LAWS. (*Phil. Mag.*, xix, 685.)—Zinc, cadmium in the form of wire, and graphite were tested. Using the Wheatstone-bridge method, the resistance of the specimens was measured with the magnetic field off and on, the wires being wound on mica frames which could be immersed in an oil bath or in a vacuum vessel for holding liquid air. Denoting the resistance of the specimen by r , and its change of resistance by δr in a magnetic field H , the ratio $\delta r/r$ is found to be proportional to H^2 . For all three substances $\delta r/r$ increases at lower temperatures; the increase from ordinary temperature to that of liquid air being 20 times in the case of cadmium and zinc, and 3 times for graphite. The change of resistance in graphite varies approximately inversely as the absolute temperature.

Glass and Metallic Grating Replicas. J. A. ANDERSON. (*Astro. Phys. Jour.*, xxxi, 171.)—The replica gratings made by taking casts in celluloid are found to give definition comparable with the original only when of small dimensions, the shrinkage during drying producing distortion. By introducing certain gums into the celluloid solution and heating the replica it is possible to produce a positive replica of the original grating. This can be coated with platinum, nickel or gold by Kathode deposition, or etched with hydrofluoric acid when wanted on glass or quartz.

Substitute for Bath-brick. The Britannia Patent Fire-lighter Co., Ltd., have patented the following process of making a polishing material. Glass works refuse, consisting chiefly of sand, emery, pumice stone and glass particles is pulverized and then passed through a refining machine to eliminate coarse material. The fine powder as obtained, or formed into bricks, is used for cleaning metallic surfaces or the like.

MECHANICAL ENGINEERING PROBLEMS IN ILLUMINATING GAS WORKS.

BY

MR. J. A. P. CRISFIELD,

Engineer of Construction, the United Gas Improvement Company, Philadelphia.

*(Presented at the meeting of the Mechanical and Engineering Section, held
Thursday, October 13, 1910.)*

[The problems which confront the mechanical engineer, who is connected with a gas plant, are brought to the notice of the reader. How these various questions may be solved to the best interests of all concerned is pointed out.]

THE business of the manufacture and distribution of gas for lighting, heating and power purposes constitutes one of the most familiar and important examples of that phase of modern civilization in which private capital, enjoying public privilege, undertakes to supply one of the conveniences or necessities of living. With the gradual recognition of the mutuality of the relations between the Gas Company and the community which it serves has come a clearer conception of the obligations of both parties to the unwritten but none the less binding contract between them, and to-day it would be difficult to find a Gas Company whose officers do not feel in duty bound to render its customers the best service in its power at the lowest rate consistent with a fair return upon the capital invested. To accomplish this result it is essential that the management of the Gas Company, in its various departments, be expert, each in its particular duty; that the work in hand shall be performed by specially educated and carefully trained men. In no department of the business is this more apparent than in the gas works itself, where technical problems of the most intricate character are continually offering themselves for solution. It is here that the young mechanical engineer begins to realize for what his course at school was intended to fit him, and gradually, as he learns to recognize the principles of efficiency, economy and the conservation of energy through their numerous and most cunning disguises he takes up his work of eliminating waste, extravagance and engineering fallacies.

The modern illuminating gas works is a highly specialized plant, designed for the duty of gasifying coal, either by distillation in an enclosed retort, or else, by making from it, hydrogen and carbonic oxide by the action of steam, and adding thereto the light-giving vapors of liquid hydrocarbons. The former method is known as the coal gas process; the latter as the water gas process.

Before discussing the mechanical engineering problems which

FIG. 1.

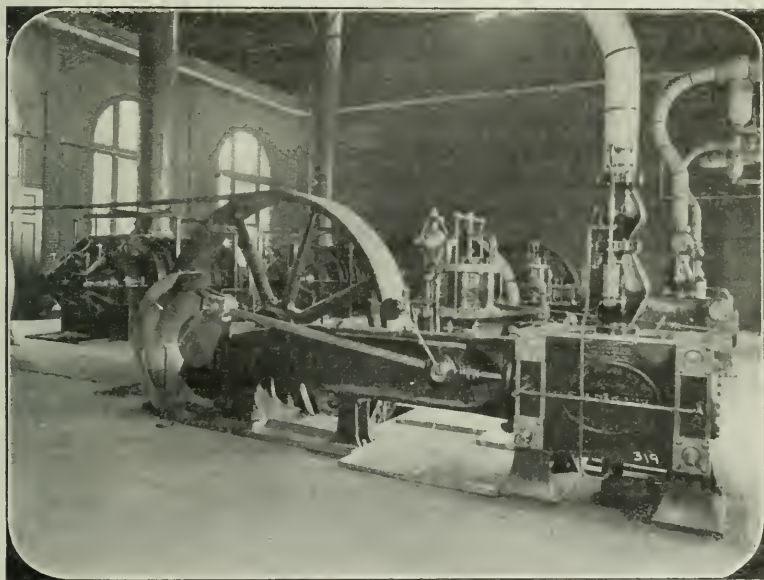


A pump room. The pumps shown in this illustration are for the purpose of handling hot and cold water, oil, tar, ammonia, etc. The services of a mechanical engineer are valuable in such work as this.

are met with in the design and operation of a gas works, it might be profitable to define that branch of engineering which is called mechanical. In the best known schools of mechanical engineering the course of instruction includes, among other things, the following subjects: Mathematics, to and including Thermodynamics; Modern Languages; Mechanical Drawing and Machine Design; Physics; General Chemistry, and Special Engineering Chemistry, including Combustion Engineering; Engineering Practice; Structural Engineering; Electrical Engineering. Hand in hand with

instruction in the theory of the foregoing subjects, the scholar is given practical work in physical, chemical and mechanical laboratories. It will be seen that this course of instruction prepares the mechanical engineer for all branches of industrial undertakings in which success depends upon the efficiency of the means and methods employed and upon other economies of operation. He is trained to save; to do work with the least expenditure of energy; to consider no economy too small to be worthy of attention.

FIG. 2.



Positive blowers compressing air from atmospheric pressure to one pound, for use in a large carburetted water-gas plant. In this case the amount of work to be done is comparatively great and the utmost economy of operation is sought by the use of Corliss engines and efficient blowers, regardless of first cost.

knowing that in the aggregate many small economies may determine the success or failure of the enterprise as a whole. The system of instruction which instils the theory of an operation and at the same time illustrates the theory in practice enables the mechanical engineer to foresee the direction in which success may be attained; and at the same time the practical instruction in the laboratories and shops saves him from the pitfalls in which the pure theorist is certain to flounder with fatal result.

In the treatment of the coal through the various stages of manufacture to the completed product, the gas manager is confronted with problems of efficiency and appropriate design; the phenomena of combustion; the handling of heavy and bulky materials; with chemical reactions of the most complicated nature. In order to insure good service, continuity of the supply of gas both as to quantity and quality, and a stable, profitable business, it is necessary so to design the plant that it possesses entire reliability, and so to operate it that the greatest net profit is obtained. With extravagance in first cost or wasteful operating methods, whether due to design or bad management, what might have been a highly attractive undertaking in which capital would readily seek investment, soon degenerates into an over-capitalized and unprofitable operation with a reduction, or entire loss, of credit, meeting finally the expensive process of a reorganization. It is therefore at the very outset that mechanical problems are met and must be correctly solved before we may intelligently determine how to build the plant so that the high efficiencies and rigid economies necessary to success may be obtained. It is not alone sufficient to know that a given piece of apparatus will perform its function with the highest efficiency; the questions must be asked: What does this efficiency cost? Will it pay to make the investment? Will it pay, for example, to purchase machinery to unload the coal, and if so, what kind of machinery? What is the cost of operating this machinery, for steam, repairs, depreciation and attendance? Would it not be wiser to avoid locking up so much money in coal-handling machinery, which may be obsolete in a few years, and rather rely upon common labor, which, though costing a little more perhaps, all things considered, does not rust, carries with it no interest charge, and is so flexible that it may be employed in numerous other operations besides the unloading of coal? All the above are mechanical engineering problems.

While the construction of the foundations of the buildings in a gas works and the strength and other characteristics of the materials employed may be properly the business of the civil engineer, and while the chemical reactions involved in the generation and purification of the gas may strictly fall within the province of the chemist, still it will not be denied that the appropriateness of the design of the structures, both as to first

cost and the facilities offered for economies in labor, the efficiency with which the chemical reactions are produced, and the thermal and mechanical efficiencies of the apparatus employed, are purely mechanical engineering problems.

One of the first problems of the mechanical engineer in the gas works is the receipt and storage of the coal for gas making and for boiler fuel. He must decide whether the amount of material to be handled will warrant the installation of mechanical unloading devices. Upon his knowledge of the cost of operating and the durability of this class of machinery depends the wisdom of the decision, and without special knowledge of this subject a mistake would probably be made which would materially affect the cost of a unit volume of the product. For example, it would not pay to invest \$5000 in machinery to handle from the car to the bin the 1000 tons of anthracite coal that will be needed in a carburetted water gas plant supplying a city of 25,000 inhabitants. The steam and labor of attention necessary to operate the machinery will cost 5 cents a ton, and the interest (5 per cent.) and depreciation (10 per cent.) will add 75 cents more. Utilizing a simple hydraulic elevator costing \$1000, a laborer, at 25 cents for his wages, will put up one ton per hour, and the interest and depreciation at 10 per cent. on \$1000 will bring the cost up to 35 cents. If to this we add 5 cents a ton for operating the elevator pump, we find that by the adoption of the second method we have saved 40 cents a ton in handling the coal. But the \$5000-elevator will handle 5000 tons at the same cost for interest and depreciation as it did the 1000 tons. Its installation, therefore, in a plant of five times the size of the one first assumed will be justified, for then the comparison would be:

For the \$5000 elevator:

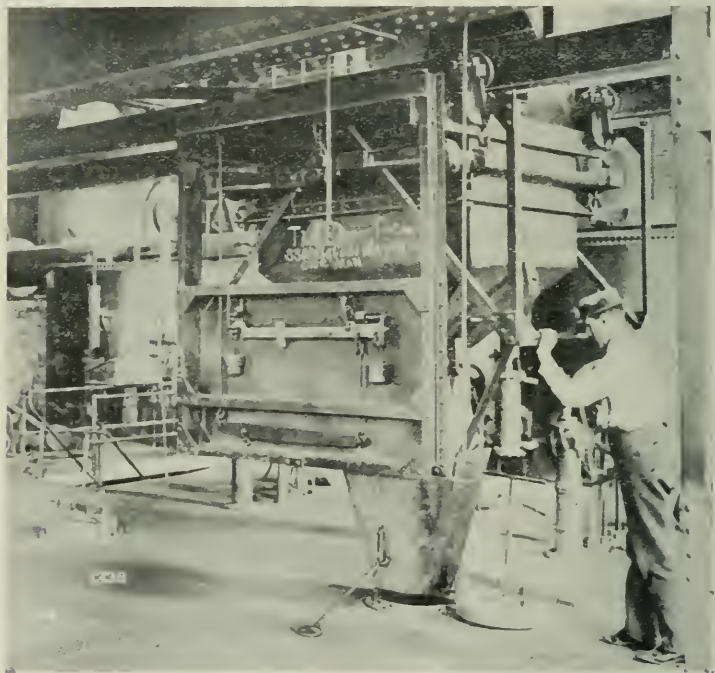
	Cents.
Interest and depreciation	15
Operating expenses	5
	—
Total cost of coal handling per ton.....	20

For the \$1000 elevator and common labor:

	Cents.
Interest and depreciation	2
Labor of operating	25
Steam for elevator pump	5
	—
Total cost of coal handling per ton	32

The above example will serve to illustrate one phase of mechanical engineering in receiving and storing coal in a gas works yard. The manager will make mistakes unless he always asks himself the question: Will it pay? Does the proposed investment bring the greatest return upon each dollar of capital? Is there not some other way of accomplishing the purpose which,

FIG. 3.



In addition to the fuel-weighing machine shown above, the mechanical engineer has applied methods of precision in the measurement of air required for blasting, the steam for producing water-gas and the oil for carburetting the water-gas. His effort has always been in the direction of replacing the old haphazard methods of gas-making with those of scientific accuracy.

during the assumed life of the apparatus employed, will show a greater net return?

Of less magnitude, but none the less necessary to the smooth running of the plant, are the mechanical engineering problems encountered in selecting the moving machinery required and in maintaining these machines in an efficient condition. For instance, the ratio of the water cylinders to the steam cylinders of

the elevator pump should be the inverse of that for the oil unloading pump, if the work in each case is to be done with good efficiency. The engines which drive the blowers for furnishing blast to the generators should be chosen only after giving due consideration to reliability, thermal efficiency, first cost and durability. The volume of business done by some particular gas company may be so small that it cannot afford the best apparatus in the market; the interest item outweighs all others combined, and the mechanical engineer recognizes this and buys a cheap

FIG. 4.



A labor-saving device—the hydraulic cylinder. By simply turning a small cock, the cylinder shown above will open and close valve gates weighing many hundred pounds.

10-horse power blowing outfit that will last long enough, or until the business has grown large enough to afford something better; but in large stations when the horsepower involved may and often does reach several hundred, the cost for interest and depreciation, even for the best that money can buy, is of less importance, compared with the cost of steam for operation; and the most efficient blowing unit obtainable should be installed, due consideration being given to the questions of durability, possible obsolescence or inadequacy in the near future. This suggests one of the most

puzzling problems of the mechanical engineer in the gas works: namely, that of selecting the right sized unit, whether it be an installation of coal gas benches, a water gas set, or a combination of both; whether he should recommend an increase of storage holder capacity or install greater generating capacity, and whether, in case greater holder capacity is decided upon, it should be located near the generating plant or at a distance; in the latter case supplemented with a pumping plant and high pressure mains. It is true that the solution of these questions involves also business judgment, for instance, in making extensions of plant. This can be done in small successive instalments, each sufficing for a short time in the future, as growth of business shall demand; this while conservative and safe, may result in ultimate high total capitalization, due to greater cost of successive small extensions and changes. On the other hand, extensions may be made on a large scale sufficing for a long time at a much lower cost for a given capacity, but this subjects the business to the risk of heavy interest charges if its growth is not rapid, or to heavy replacement costs if improved apparatus be substituted for old. Sound judgment as to business prospects is here required, but after its exercise there is equally important use for the knowledge and judgment of the engineer, even if much that is ordinarily called business judgment is not itself the application of mathematical or of engineering principles.

Having designed and built a gas plant, with constant consideration of the result to be obtained, with an eye to thermal, mechanical and labor efficiencies, with the least expenditure of money compatible with the utmost reliability and fair durability, the mechanical engineering problems of operating must be met. One of the most important of these is the quality of the raw materials. Since it is the business of the mechanical engineer to secure the greatest possible quantity of heat units and light units in the finished product for each dollar expended for raw material, it is important that he does not handicap himself at the start by purchasing inferior raw materials. Although there is a growing tendency towards the purchase of coal on the basis of its heat value, still this practice is not by any means general, and it is customary for the engineer to purchase coal regardless of the percentage of fixed carbon, volatile combustible, ash, sulphur and water. How important a matter this is may be seen

by reference to two analyses given below of samples of coke which, when good, is a most excellent gas-making fuel. Two analyses of bituminous steam coal are also given.

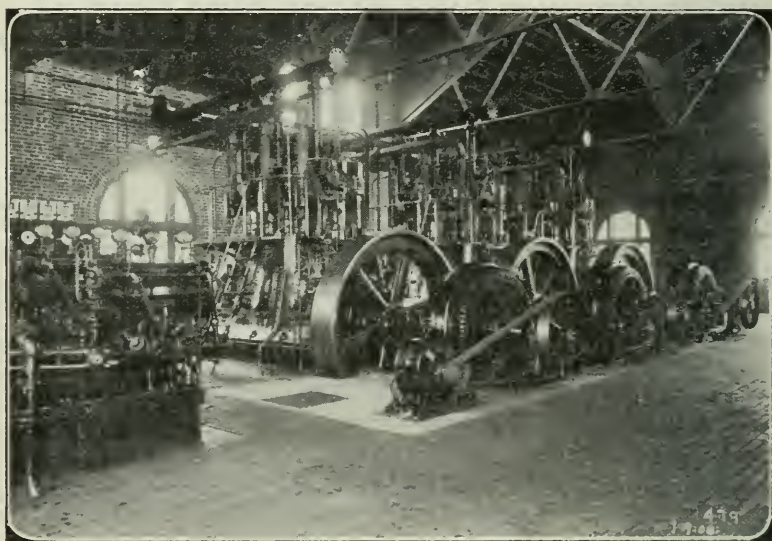
	COKE.		STEAM COAL.	
	No. 1.	No. 2	No. 3.	No. 4.
	Per cent.	Per cent.	Per cent.	Per cent.
Moisture.....	15.0	1.5	0.73	12.71
Volatile combustible.....	5.0	3.0	17.43	28.62
Ash.....	15.0	5.0	4.03	20.78
Sulphur.....	1.0	0.5	0.62	3.69
Fixed carbon.....	64.0	90.0	77.71	34.87
	100.0	100.0	101.12	100.67
B. T. U.			15,178	8,840

The sample No. 1 had been exposed to heavy rains, or it had been flooded when quenched, was badly burnt off in the first place and was the product from a seam of coal containing much ash and sulphur. From a mechanical engineering stand-point only the fixed carbon is of certain value for making carburetted water gas. Consequently the gas manager has actually paid 40 per cent. ($0.9 \div 0.64 = 1.4$) more for his fuel in purchasing sample No. 1 than in purchasing sample No. 2. Although he may not be able to control the dealers in the matter of the analysis of their coal, he is, to some extent, in command of the situation, owing to the fact that he may restrict his purchases to certain coal fields where the quality is good and uniform. He may also insist upon proper methods of quenching, and upon the shipment of the coke in covered cars or failing to be able to keep the coke dry en route, he may find that it will pay to build sufficient storage at the works to permit a partial drying out under cover.

One of the most troublesome problems to be met with in a gas works is that of labor. It might be said that this is not particularly a mechanical engineering problem, since all employers of labor must encounter it. Still, it is more the problem of the mechanical engineer than of any other, because he is, by education and experience, best fitted to reduce the amount of human labor required, and this is what he is continually attempting to do by the adoption of labor saving appliances, such as bucket elevators,

belt conveyors, hydraulically operated valves and lifts, compressed-air drip pumps, mechanical stokers for coal gas retorts and for the boilers. In this field of endeavor he has no competitor. In common with many of his mates in other industrial enterprises, the mechanical engineer in the gas works has the problem of boiling water for making steam. No one will admit that this is, as a rule, intelligently and efficiently done to-day. And yet, knowing this, our practice and methods are not greatly different from what they were two thousand years ago. It

FIG. 5.



A Diesel engine power plant in which water-gas tar is the fuel, and where 25-cycle A. C. current is produced for power purposes, with a consumption of one-tenth of a gallon of tar per horsepower hour

is still believed that in boiler practice 50 per cent. excess air of combustion is necessary for best results, whereas, in almost every other form of combustion with which we are familiar, science has reduced the necessary quantity of air to the theoretical amount. As illustrating the waste due to 50 per cent. excess air in the ordinary boiler efficiencies, it may be calculated that such a percentage of excess means an increase of 10 per cent. in the total fuel consumed. In the year 1909 there were used in the

United States under boiler furnaces for producing steam, approximately 340 million tons of coal. If this steam could have been produced by the combustion of coal with the *theoretical* amount of air, the saving would have been 34 million tons which, at an average price of \$3.00 per ton, would amount to one hundred million dollars. Which of our young mechanical engineers, who are now earning their spurs at their chosen profession, will undertake to stop this waste and show us how to advance in the art of producing steam?

In a gas works a large percentage of the cost of the finished product is incurred in the generator of the water gas plant, or in the furnace of the coal gas bench. Here the problem is the apparently simple one of the combustion of carbon at temperatures above 2000° F. However, owing to impurities in the fuel, such as ash of variable fusion temperatures, extra complications are introduced which make the operation extremely difficult. Clinkers—the bugbear of everyone who burns coal, sooner or later, as the operation continues—upset all nicely calculated adjustments, and, unless means and methods are adopted to vary the air and steam of combustion so as to bring about a readjustment, serious losses will result, both in efficiency of production and in the quality of the finished product. It is now that we find the mechanical engineer hard put to it, and it is only by combining his knowledge of the theory of combustion with his practical experience in doing things that he is able to supply the demand for gas and render the good service which the community expects of him. Lack of such knowledge and practical resourcefulness must be compensated for by increased investment for spare machinery, making it still more difficult to obtain the desired profit.

Many other interesting and important mechanical engineering problems might be mentioned, but enough has been said to indicate that the business of gas making is largely the work of the mechanical engineer. Even the abstruse reactions within the coal gas retort and the water gas carburetter are not entirely outside his field. Though they properly belong to the chemical engineer, still, the education of the mechanical engineer of to-day fits him for such work, should he care to specialize in it. Indeed, so satisfactorily does the young mechanical engineer attack and

master the work in a gas plant, that some gas companies have entirely restricted additions to their engineering forces to this class.

When we consider the immense amount of intelligent work which has been expended upon the engineering problems in a gas works, it is not to be expected that any very great economies in manufacture will be made. What reductions in the cost of the finished product will be made will be accomplished by close attention to the small savings possible in increasing thermal and mechanical efficiencies and in the substitution of mechanical appliances for human labor. These are problems which will be solved only by the trained mechanical engineer.

Heat Capacity of Metals and Metallic Compounds. H. SCHIMPF. (*Zeit. Phys. Chem.*, lxxi, 257.)—The heat capacities of 15 pure metals and 29 metal compounds have been determined by the method of mixtures in the three temperature intervals 17°C. to 100°C. , 17°C. to -79°C. and 17°C. to -190°C. , and the results agree very closely with the calculated values of the specific heats. Between $+50^{\circ}\text{C.}$ and -150°C. the temperature coefficient of specific heat decreases with rising temperature for both metals and the inter-metallic compounds, except in the cases of lead and bismuth. In general the difference between the observed and calculated values of the specific heats of the inter-metallic compounds lies within 4 per cent. The observed specific heats of magnesium alloys are lower, and those of antimony alloys are higher than the calculated values. The atomic heats of metals and metallic compounds increase with increasing temperature.

Tar Roads. (*Eng. Rec.*, lxii, 7.)—In 1909 the Massachusetts State Highway Commission used English spraying machines to apply tar coatings to road surfaces. The tar is heated by a coil supplied with steam from a traction engine. The tar is kept under pressure by pumps geared to the wheels of the truck so that the motion of the tar spraying machine develops the necessary pressure. The hot tar is spread through a number of small nipples which throw a fine spray, and spread it upon the road in a thin and even coat. A hood over the nipples prevents the tar from being blown to one side by the wind. When a heavy grade of oil is used and applied hot at the rate of half a gallon per square yard the cost is said to vary between 6 and 11 cents per square yard, including material, labor, and the surface covering of sand, gravel, or stone-screenings.

VACUUM-TUBE LIGHTING.

BY

D. McFARLAN MOORE.

*(Presented at the Stated Meeting of the Institute held Wednesday,
September 21, 1910.)*

[The paper refers to the investigations in connection with vacuum-tube lighting and the results obtained by the author during the course of his experiments which have covered a period of sixteen years.]

VACUUM-TUBE lighting is the term that is usually applied to that form of light produced by the flow of a current of electricity through various kinds of rarefied gases confined within clear glass tubes. Such tubes under the name of the Moore Light to-day occupy a position in the great field of illumination, that is most important. Their light is produced in a way that is radically different from all of the ordinary methods long in use. The resultant illumination possesses distinctive attributes that command the earnest attention of all scientific men now, and is the harbinger of still greater scientific triumphs of the immediate future.

It is very interesting to note that although vacuum-tube lighting is a comparatively new commercial industry, nevertheless its underlying principle was noted at the very beginning of electrical science. In fact the very first electrical machine ever invented and constructed produced a small glow of vacuum-tube light as a by-product. I refer to the glass sphere of Hawksbee, who generated static electricity from it in 1750 by the friction of his hands as it revolved in trunnions. The air had been exhausted from its interior to such an extent that the static electricity caused the residue to appear as a suffused glow. But it was not until about a hundred years later that any real progress was made in this direction. It was then that Geissler in Germany attached the two high-potential terminal wires from an induction coil to the two ends of a small glass tube into which he had sealed short pieces of platinum wire and then exhausted the air from the tube. The high potential current caused these little tubes

to apparently glow quite brightly for a few moments before the vacuum deteriorated to such an extent that the light became extinguished. Crookes in 1879 made his famous investigations with similar tubes, but due to the extremely light degree of vacuum he employed the quantity of light produced was less rather than greater so that when your lecturer commenced his investigations sixteen years ago, the only foundation upon which to rest any hope for a new and improved method of producing commercial electric light was the extremely meagre Geissler

TABLE I.

CHRONOLOGICAL DEVELOPMENT OF SALIENT FACTORS OF THE MOORE LIGHT.

Time	Source	Break	Coil	Lamp	Gas or Chemical
1894	Battery.....	Air vibrator	Primary and secondary	Geissler tube.....	———
1894	Street circuit	Vacuum vibrator	Primary only...	Bulb lamps.....	———
1896	Street circuit	Vacuum vibrator	Primary only...	Tubes, external caps	Wood alcohol
1898	Street circuit	Vacuum vibrator	Vacuum rotator	Tubes, external caps	Wood alcohol
1899	Low fre. generator	None.....	Resonance coils	Tubes, external caps	Wood alcohol
1901	High fre. generator	None.....	None.....	Tubes, external caps	Aubepine
1902	High fre. generator	None.....	High fre. transformer	Tube 100 ft., terminals in box	Graphitic acid
1903	High fre. generator	None.....	High fre. transformer	Internal electrodes	Rosalic acid
1904	60 ~ Street	None.....	Standard transformer	Internal electrodes	Rosalic acid
1905	60 ~ Street...	None.....	Standard transformer	Internal electrodes	Air through-feed valve
1906	60 ~ Street...	None.....	Standard transformer	Internal electrodes	Nitrogen through-feed valve
1906	60 ~ Street...	None.....	Standard transformer	Internal electrodes	CO ₂ through-feed valve
1909	60 ~ Street...	None.....	Standard transformer	Internal electrodes, semi-portable window	CO ₂ through-feed valve
1910	60 ~ Street...	None.....	Standard transformer	Portable window, invertable valve	CO ₂ through-feed valve

tube. The outlook was dubious, nevertheless theory pointed that way, and once more important scientific advance becomes debtor to "blind faith" that struggles dauntlessly forward no matter how dark and foreboding the prospects. The watchwords have ever been "try once more for the last time" and "there must be some way out." Due to unrelenting toil and many thousands of disheartening experiments it can now be said, "something useful is attained."

It will be noticed by referring to Table I that the five most

salient factors of this system of illumination can be helpfully considered as the links of a chain and that the development of the system consisted essentially in the continual necessity of strengthening first one link and then another.

One extremely important advance will be noted in 1899 when all "make-and-break" systems were finally superseded by static transformers receiving their energy from alternating dynamos, and again in 1905 when the automagnetic gas-feed valve made its appearance and began to occupy a place of great importance which it still holds. One of the first tubes installed equipped with such a feed valve is shown in Fig. 1 (Madison Square Garden). This tube is still in nightly operation and produces five times

FIG. 1.



Madison Square Garden, N. Y. Lighted with Moore tube.

as efficient an illumination as that of the incandescent lamps previously used to illuminate the same area.

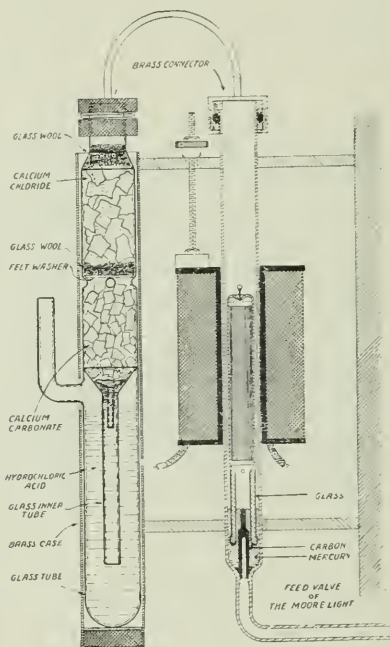
The heart, or rather the lungs, of the whole system, since it breathes, is the feed valve, which is shown in detail by Fig. 2. The small carbon plug when not completely covered by the mercury permits air or any gas to filter through it and then to pass into the large light-giving tube. The mercury of course cannot pass through the pores of the carbon and when it covers the carbon entirely, absolutely shuts off the passage of any gas through the carbon plug. The tip of this carbon plug is only exposed when the glass tube surrounding it is raised which thereby causes the surface of the mercury to lower.

The automatic manner of lowering and raising the surface of the miniature pool of mercury, that is, opening and closing this gas tube, is best shown diagrammatically in Fig. 3.

The glass tube, the lower end of which rests in the mercury, has its upper end filled with iron wire which acts as the core of a solenoid, that is, connected in series with the low tension side of a transformer, fed from the street alternating current mains.

Therefore, this gas-feed valve opens and closes as the cur-

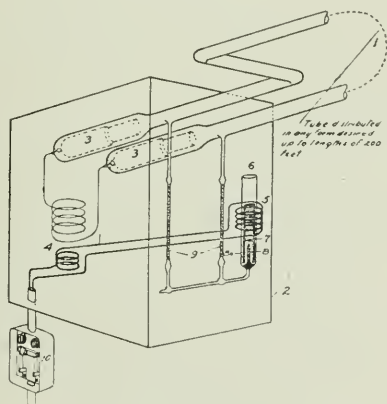
FIG. 2.



rent flowing through the solenoid becomes greater or less in direct proportion as the potential flowing through the gaseous conductor of the long light-giving tube changes. This current gradually becomes slightly greater as the conductivity of the gaseous-conductor increases, due to the degree of vacuum in the tube becoming higher, as the quantity of the gas in the tube is used up by the passage of the electric current. The momentary influx of a fresh supply of gas therefore automatically

shuts itself off by the weakening of the solenoid. A careful study of the current curve plotted in Fig. 4 makes the simple though effective action of the valve perfectly clear. It is so frictionless that it often acts with perfect reliability every minute for 10,000 hours. Any desired kind of gas can be fed to it, but it has been found that carbon dioxide yields a spectrum that is the equivalent of daylight. When this gas is desired it is generated automatically as shown by a portion of the apparatus in Fig. 2. That is, the lighting tubes' automatic demand for gas creates a slight vacuum that raises the hydrochloric acid into contact with the calcium carbonate, but only for a few moments at a time.

FIG. 3.



1, The Moore tube; 2, terminal box; 3, terminal electrodes; 4, transformer; 5, feed-valve coil; 6, glass tube of feed valve; 7, glass and iron wire displacer; 8, porous plug; 8a, mercury; 9, sand resistance tubes; 10, 220-volt, 60-cycle a. c. supply.

or until the very small amount of gas needed is generated.

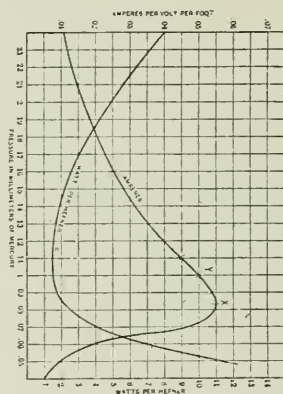
The automagnetic feed-valve solved a problem that seemed impossible because the factors involved were of such a delicate order. Primarily the problem was to maintain within $1/100,000$ of an atmosphere a tube volume of about 5000 cubic inches at a degree of vacuum corresponding with $1/10,000$ of an atmosphere. This extremely small permissible variation in gaseous pressure is not discernible on a barometric column, therefore the solution of the problem could hardly be approached by purely pneumatic or mechanical means but the electrical solution is due to the fact that minute changes in gaseous pressure correspond

to comparatively great changes in the conductivity of the gaseous-conductor. That is, a change of $1/100,000$ of 1 per cent. of an atmosphere corresponds to a change of about 4 per cent. in the amperes flowing through the light-giving tube.

If the valve on such a tube is intentionally made inoperative, the light of the tube almost immediately begins to flicker and in a few minutes the light literally dies out for want of breath.

Many uses have been made of the light; it has been installed for banquets (as will be seen in Fig. 5), for use in hardware stores, machine shops, shoe stores, offices and art stores, baths, florists' shops, show windows, at ribbon counters, in silk mills, in photo-

FIG. 4.



graphic studios, and a mile of yellow Moore light is in operation at the New York Post-Office (Fig. 6). The latter is produced by feeding it with automatically prepared nitrogen gas, resulting in a most efficient form of illumination.

The long tubes are constructed in innumerable shapes, but there is a small and compact or portable form of tube, which is designated "artificial window." When these "windows" are supplied with CO_2 , the spectrum of average daylight is produced which has proven itself most valuable to many classes of business in which color values are of prime importance. For example, 10,000 operatives in dyeing establishments were able last winter to work on full time solely

because of the white Moore Light. No other form of artificial light has enabled the dyers to operate at night or on dark days. All of the primary colors as well as their shades are seriously distorted by all forms of light except that from the carbon dioxide vacuum-tube, a fact substantiated by all of the highest commercial and scientific authorities including the official report of the U. S. Bureau of Standards.

Commercializing the Moore Light has involved the design

FIG. 5.



Dinner in honor of President Taft, Passaic, N. J., May 9, 1910. Lighted with Moore tubes.

and invention of many auxiliary devices, such as the tools for cutting and joining the glass tubes, with suitable pumps for exhausting them.

Hundreds of experiments were necessary in determining the best kinds of gaseous conductors for various purposes. But this aspect alone of this new industry is so vast that it will probably be some time before it can be claimed to have been thoroughly explored. It would be difficult indeed to cite a field of scientific

research more full of promise. Very probably the gaseous-conductors now used correspond to the old carbon filament or a gas jet without a mantle. The latter forms one of the best illustrations of the enormous advantages accruing from selective luminescence. Gases will be found which when placed in the path of the vacuum-tube discharge or current flow will increase the efficiency of this light source, just as thorium and cerium did so wonderfully for the open gas flame. When this occurs

FIG. 6.



Installation at New York Post-Office, yellow light.

a very long step will have been taken towards the theoretical limit of efficiency for producing useful light for the human eye. Cheaper light is demanded by commerce as well as science, but the limit has evidently been reached so far as obtaining it by heating solids, while on the contrary we are just beginning the fight on the principle that is correct theoretically, viz., obtaining light by setting up the proper rates of vibration for the various colors, in gases, either by electrical or chemical means. There

is every reason for believing that a complete solution will be effected by adhering to the electrical means now employed but nature also stands ever ready with her fire-fly, like an open challenge to the scientific world to produce commercial light in the same manner, which is evidently chemical.

The necessary factors seem to be sodium or magnesium, formic acid and oxygen. But commercial electrical luminescence will doubtless be the next great and necessary stepping-stone, to hold for a time the attention on the grand march of light development, and to a future generation may be left the complete mastery, through commercial, chemical luminescence.

[NOTE.—Numerous lantern slides covering the historic as well as the technical side of the subject were shown during the reading of the paper and specimens of the white and yellow lights were in operation. Cloths of various colors were shown under the ordinary tungsten light and under Moore white light with a view to demonstrating the value of the latter as a medium for bringing out the natural colors.]

Temperatures of Electric Steel Furnace. PROF. BERNHARD NEUMAN. (*Iron Age*, lxxxvi, 6.)—The Professor discusses the claims of high temperatures for steel refining in the electric furnace. He refers to some temperature measurements made by Prof. J. W. Richards at the Heroult furnace of the Illinois Steel Co., at South Chicago, which were so low as to indicate that the electric steel on the average was not hotter than that in a Bessemer converter. The reason is that Bessemer steel is refined for only one or two hours, so that the steel is of good average quality, C=0.4, Mn=0.4, S=0.03, and P=0.03. Prof. Neumann gives temperature measurements made in a Nathusius furnace at Friedenshütte, which were about the same range as those noted at South Chicago.

Tayabas Petroleum. G. F. RICHMOND. (*Philippine Jour. of Sci.*, v, 1.)—A sample of crude petroleum, typical of that found in the Tayabas province, P. I., resembled Pennsylvanian petroleum in containing a fairly high proportion of volatile hydrocarbons, in having a paraffin base and in being free from sulphur. The proportion of volatile constituents boiling below 150° C. was greater than in most petroleum oils: sp. gr. 0.831, initial boiling point 70° C.; first fraction (light oils) 70° to 150° C., 36.5 per cent.; second fraction (burning oils) 150° to 300° C., 48.75 per cent.; and residue, above 300° C. (by difference) 14.75 per cent. It contained 30 per cent. of unsaturated hydrocarbons which could be removed by acid. It might be described as essentially a paraffin petroleum.

Ferrosilicon Manufactured in the Electric Furnace. F. W. HINRISCHEN. (*Mitt. Kgl. Materialprüfungsamt*, xxviii., 283.)—This paper relates to investigations as to the cause of, and means of prevention of, accidents arising from the poisonous and explosive gases evolved from this material. These gases are chiefly phosphor-ettred hydrogen derived from the calcium phosphide. Some samples also contain arseniuretted hydrogen. The most dangerous grades are those containing from 30 to 70 per cent. of silicon. This article is well worth careful consideration by manufacturers, carriers and users of electric ferrosilicon.

Development of Papers Giving a Visible Image of Silver Chloride. J. DESALME. (*Bull. Soc. Franc. Phot.*, i, 207.)—Developers containing an amino group are the most suitable for the physical development of printing-out and similar papers. Developers containing two or more hydroxyl groups are not nearly so active. *p*-Aminophenol is the most useful of all the developers tried, the diamino compounds being so energetic as to be beyond control. By neutralizing the amino group, *e.g.*, with an organic acid, the action is retarded and the tone modified. Dimethyl-*p*-phenylene-diamine is less rapid than *p*-phenylenediamine, whilst monoacetyl-*p*-phenylenediamine has no developing power. Methyl-*p*-aminophenol (metol) acts less energetically than *p*-aminophenol, but both are valuable physical developers when used in conjunction with tartaric, citric, or acetic acid.

Thermal Conductivity of Fire-Clay. J. K. CLEMENT AND W. L. EGY. (*Met. and Chem. Eng.*, viii, 414.)—The test-pieces were made into cylinders about 40 cm. long and 12 cm. in diameter with a hole through the centre for the heating coil, and four longitudinal holes, about 3 mm. in diameter, for the reception of thermocouples for the measurement of the temperature. The temperature inside was raised to between 400° and 900°C. during a time of 3 to 5 hours, and then kept constant for 2 or 3 hours more. When the outer couple showed a temperature constant to 0.1°C., the readings were taken. The cylinder was then broken across and the distances of the holes from the centre measured. From these data, together with the voltage and current readings of the heating coil, the conductivity can be calculated. It was found that in the case of two coarse fire-clays the conductivity was constant at 0.00264 and 0.0036 Gm. calories per cm. per second per 1°C. respectively, while for two finer fire-clays there was an increase from 0.0021 at 350°C. to 0.0022 at 600°C., and from 0.00245 at 500°C. to 0.0026 at 800°C. respectively. Knowing the thermal conductivity of brick the dimensions of a furnace, and the outside temperatures of the walls, the quantity of heat transmitted through them may be calculated. In the case of a 210 h.p. Heine boiler this was found to be 43,400,000 calories per hour.

CELLULOSE.

BY

MR. CARL G. SCHWALBE.

[Translated from the *Moniteur Scientifique*, 24, 825.

By W. J. Williams, F. I. C.]

THE first attempts to substitute other prime materials for rags, old linen, or cotton waste for the manufacture of paper date from the middle of the eighteenth century. Even at this time these prime materials were getting scarce. Christian Schaeffer of Ratisbon, attempted in 1765 to make paper from wasp-nests, turf, straw, hay, the twigs of hops, from brush broom, and even from wood, but his efforts brought no results except the contempt and jeers of his contemporaries; the time had not yet come to realize this idea, and moreover the scarcity of rags had not yet become pressing. But when the development of daily newspapers, and the necessity of satisfying the demands arising from the extension of popular instruction, had made these ideas acceptable, the search for substitutes for rags became permissible; thus it was that towards the middle of the nineteenth century, the attempts of the weaver Keller to de-fibre wood so as to obtain a pulp, to replace the pulp from rags, were favorably considered. There should be remembered, too, the attempts made by Melliers, among others, who frequently tried to treat straw so as to extract from it a pulp which could be used industrially. Cellulose treated with soda soon followed the mechanical wood-pulp and straw-pulp. In fact, the process of treating wood, as well as straw with caustic alkalies or alkaline earths became a success. Moreover, very soon after this alkali process had been brought from America to Europe by Houghton, it found a competitor in the chalk process, or in the sulphurous acid or bisulphite process. The names of Tilghman and of Ekman are connected with the first experiments made in Germany to use calcium sulphite or magnesium sulphite for this treatment. At this time, this process which had been kept secret fell into oblivion. The energy and determination of

Mitscherlich and his licensees developed a practical industrial process, which, concurrently with the analogous process of Rittner-Kellner, soon brought the new industry to an extraordinary stage of development in the short space of 25 to 30 years.

The production of cellulose amounted to 1,600,000 tons, of the value of \$80,000,000; the production in Germany was estimated at 564,000 tons, worth \$28,000,000; the proportion of cellulose treated with caustic soda was very small. This was due to the fact, that for various reasons, still disputed, the bisulphite process of treating wood seemed superior to the soda process. However, in spite of the considerable extension of this process, in spite of the great progress it has made as to the yield, both in quantity and quality of the product, hence the certainty of the methods of manufacture, still the cellulose industry depends almost entirely on empiricism. The chemical composition of the raw material, wood, and of its manufactured product, cellulose, is still almost completely unknown to us.

The cellulose industry and its allied industries of cotton, gun-cotton, and artificial silk are thus in an analogous condition to some other industries, for example, the leather industry; from this point of view they are in a totally different condition to the great industry of inorganic chemical products or of coloring matters. In the case of these latter industries, the exact chemical knowledge of their raw materials and of their intermediary products has allowed them to advance very methodically and in well-chosen paths; and this has made their recognized brilliant development possible.

May I be permitted here to make a rapid sketch of what the cellulose industry and its allied industries are; to point out what problems are not yet solved, the solution of which is demanded as much by the chemist as by the technical man; and to express how necessary it is to base these industries upon more solid chemical knowledge than they actually possess at present?

To begin with, let us consider the manufacture of mechanical wood-pulp: 500,000 tons worth \$12,500,000, are produced annually in Germany. At first sight this manufacture does not seem chemical. In fact, the decorticated wood is crushed flat between millstones and under a stream of water, either per-

pendicularly to the course of the fibre or with the fibre; the fibrous pulp thus obtained is refined, freed from splinters of wood, and then worked in different ways so as to yield various products, such as straw-board, but chiefly the substance to which a small quantity of cellulose is added to make the paper for the daily journals.

If one of the stages which this process has lately reached is studied, that known as the method of defibring by the hot process, which came from America, we are plunged at once in a chemical problem. In this method, as a preliminary treatment, recourse is had simultaneously to boiling water and a very high pressure, working at as low a temperature as possible.

Boiling with water under these conditions, when it is for a short time only, appears to dissolve a certain part of the wood and to yield a very large quantity of very long fibres, with a small residue of broken fibres. The effect naturally goes much farther if the water is allowed to act for too long a time and under greater pressure. To obtain very resistant fibres, certain constituents of the wood are dissociated, and then the custom is to recover them by the production of the brown mechanical pulp. This pulp is specially used to make a very strong leather-board. Unfortunately, carbonization begins during this process. According as the temperature and the pressure (4 atmospheres on the average) are more or less high, a correspondingly more or less marked brown color is produced. Is this due to the formation of humus? As vanillin and acetic, formic, and oxalic acids are found in the residual lye, it is not improbable that oxidation is set up.

It has been attempted to remove this extremely troublesome brown color by bleaching, but in vain. However, there appears to be some hope of success of preventing the production of this brown color, that is of preventing the oxidizing agents from acting; to effect this, either the air in the autoclave (digester) and in the pores of the wood is removed by producing a vacuum in the autoclave, or, before boiling, the wood is impregnated with a solution of a reducing agent, such as sodium sulphide. Besides this question of discoloration, other technical problems present themselves; in any case there is the utilization of the residual lye, which may contain as much as 10 per cent. of the weight of the treated wood. The solution of this problem

opens up many scientific questions: From what portion of the ligneous substance are the organic acids derived? Is the process an hydrolysis? Above all, what is wood? And if in the course of our researches we take up those which refer not only to the mechanical pulp of brown wood, but also those which concern the white mechanical pulp, how is it that the paper made from mechanical wood-pulp turns brown so quickly? And how shall we determine the amount of wood in a mechanical pulp when it is mixed with other fibrous substances? Quite recently Messrs. Cross and Bevan have answered this question by an approximate solution. A solution of phloroglucin in hydrochloric acid gives a beautiful purple color to wood, which has long been used for the colorimetric determination of the quantity in mechanical wood-pulp. But the two English savants have found that, as well as this color reaction, there is a notable absorption of phloroglucin by the wood-pulp, in fixed proportions by weight. If wood-pulp, or a substance containing wood-pulp, is placed in a solution of phloroglucin of known strength, and at the end of a certain time the then strength of the solution is determined, the quantity of phloroglucin consumed allows a conclusion to be drawn as to the amount of wood in the pulp.

The absorption of an inconsiderable quantity (6 to 7 per cent.) of phloroglucin by lignin, led Cross and Bevan to recognize in this fact a proof that only the ketone compounds and not the aldehyde compounds act in this way, for the aldehyde compounds will have been oxidized by the chlorine and could not give this reaction. This assumption, formulated by the English scientists, on the presence of compounds reacting in the lignin, leads us to recognize quickly the hypotheses which have been made on the subject of lignin. Scientists are agreed in admitting that there must be an aromatic nucleus in lignin. Czapek, by heating saw-dust (wood shavings) in water under pressure, obtained a substance which he called *hadromal*, which was recognized later, thanks to the work of Graefe, as being a mixture of vanillin, methyl furfurol, and pyrocatechin. Graefe concluded that from the quantity of methoxy compounds in the wood the quantity of vanillin could be deduced, and further that this must be the chief constituent of lignin. It is not necessary, however, that all the methylic compounds should

produce the vanillic nucleus, as Fromherz has shown. Moreover, it appears very probable, according to the recent researches of Klason, that lignin is composed of coniferyl alcohol (a compound closely related to vanillin) and of a derivative of this alcohol, oxyconiferyl alcohol, for four similar nuclei have been formed by separating the water. This constitution would be allied to that of the carbohydrates and should be of the same character as a glucoside. In fact, when water acts upon wood, a solution is obtained containing 10 to 12 per cent. of a wood-gum, which is a carbohydrate, from which proportion the content of lignin is deduced as 26 to 30 per cent. It is remarkable that invariably only 1.4 per cent. of carbohydrate is found in the residual lyes of the bisulphite process: it must be admitted then that the pressure, the rise in temperature, and the chemical agents have a destructive action. Let us remark, in passing, that it is possible after that to answer the question so many times asked, whether it is not possible to manufacture vanillin by utilizing either the residual lyes derived from the hot process of making wood-pulp or the lyes from the bisulphite process. At the very low price of \$4.55 per pound, which is the present price of vanillin, no one would be interested sufficiently to make the extraction. Besides, it must first be considered that the demand for vanillin is not so important now, and that if this question was solved, it would not solve the problem of utilizing not only the cellulose but also the lignin of wood.

These considerations have led us face to face with that problem of the cellulose industry which is the most difficult to solve and at the same time the most important. What will become in the future of those innumerable organic substances dissolved in water, when our rivers refuse to accept them; or what will remain, even of the business itself, when the laws protecting water-courses, threatening even now, become active, and forbid us to throw the residual lyes into them in such large quantities as has been done up to the present time? The quantity of organic matter dissolved in water is nearly equal to the 564,000 tons of cellulose, and a means must be found of destroying it.

Having given the outline of this discussion, it is impossible to detail the numerous processes which have been suggested for the utilization of the residual lyes. However, that attention may be called to the most recent of the processes in this direction,

it will suffice to mention the one now on trial at Langen in Hesse. By heating the residual lye from the chemical wood-pulp of the bisulphite process in the presence of acids and, when required, applying pressure and adding formaldehyde, a tough and plastic body precipitates. The question now is to ascertain if this product really has such desirable properties as will allow of its use in such a way as to assure a large demand for it. This product may be considered as cellulose pitch. This is the name given to the product obtained at Walsumam Niederrhein by evaporating the residual lyes nearly to dryness, and has proved to be an excellent agglutinant for the agglomeration of powdered minerals. The whole question lies in knowing if, in such a case, the cost of evaporation would not be too great, in which event the process is of no value from an economic point of view.

In the production of cellulose by soda, the residual lyes need not cause any uneasiness. These lyes are concentrated and then calcined to extract the alkali contained in them.

In this case the organic matter which the lyes contain partly furnishes the fuel necessary for their recovery. On the other hand, to compensate for the absence of the problem of how to get rid of these residual lyes, this process has one great drawback, which explains why it is not more frequently adopted; the treatment of these residual lyes sets free very noxious fumes, which, up to the present, cannot be avoided. This inconvenience and the small yield of cellulose are the reasons for the abandonment of this process in Germany. At this moment, laws are being prepared in Scandinavia, with a view to the total suppression of the noxious fumes from this manufacture, and thus the existence of the industry of making cellulose by the soda process is strongly menaced in those countries.

But the utilization or the suppression of the residual lyes are not the only important problems. Cellulose, whether obtained by boiling with alkalies or from an acid solution, must be bleached. This does not mean merely to destroy the very slight color of the chemical pulp of heated wood, but rather to carry out an operation, which is a true chemical attack accompanied by a great loss of weight (4 to 10 per cent. in the case of bisulphite cellulose). There is no doubt that the discoloration would be much more intense and much more difficult to destroy

in the case of caustic soda cellulose than it is with bisulphite cellulose. We do not know the nature of the color; besides this problem has remained unsolved in another industry, the elder sister of the cellulose industry, the manufacture of cotton, for the coloring matter which causes the discoloration of raw cotton is not clearly recognized; it is only known that it seems to act as a caustic, a destroyer. As it seems to us, instead of completing the treatment by bleaching, it should be asked if the bleaching cannot be done during the treatment? Experience has taught that if the treatment is pushed too far the quantity and quality of the product are influenced to a considerable degree. The treatment should be considered as a sort of hydrolysis, so that on continuing it too long, not only the lignin, but also the cellulose itself is attacked. Thus in the soda process, it must be admitted that after the solution of the compound (analogous to an ether) which is formed by the cellulose and the lignin, the lignin is changed into lignic acid by the alkali, for Lange obtained not only cellulose, but also a certain quantity of lignic acid, by fusing wood and alkali together. The theories that have been suggested as to the reactions in the bisulphite process are very diverse: whether the acid radical of the sulphurous acid remains in the state of a double salt; or whether it reacts with the aldehyde compounds; or again whether it forms ethers or sulphonated acids. The last view is the one most accepted, thanks to the work of the Tollens laboratory, in fact the presence of a sulphonated acid combined with the lignin, has been recognized in the residual lyes of the bisulphite process; and from this compound, though with great difficulty, by means of alkalies, a sulphonated acid has been separated at the same time as a lignic acid, apparently identical with that obtained from the soda process.

It seems to us that these considerations only concern lignin. But what can we say relatively about cellulose? Is there really a unique cellulose which is isolated when the boiling is not continued too long? Are there fixed quantities of a less stable cellulose which go into solution? It is certain that this is the case in the soda process of making cellulose; in fact the yield is 15 to 25 per cent. less than that obtained in the bisulphite process, and the product even after bleaching does not always appear identical with cellulose from cotton; for among other

distinctions it reacts with phenylhydrazine, and forms furfural when distilled with hydrochloric acid. Are these reactions due to the existence of a mixture of several different celluloses? or are they due to a *single* cellulose? or again are they due merely to impurities, difficult to remove? What will remain when these impurities are eliminated? It is plain there is no lack of unsolved questions and that all of them, more or less, await their solution by work based on experiment. But that is not all: the different kinds of cellulose formed during the boiling show still more subtle differences and present an immense field for purely chemical research, for, up to the present time, the various kinds cannot be completely differentiated by their physical properties. There are certainly different kinds of cellulose pulp obtained, according as they are treated by slow boiling as in the Mitscherlich process, or by rapid boiling as in the Rittner-Kellner process.

Are all these different hydrates one and the same cellulose like that of cotton? These questions remain for the most part unanswered. Only one of the questions relating to the carbohydrates has as yet received a reply. It is now known, at least, that by excessive treatment of the bisulphite cellulose, a transparent substance is obtained, looking like parchment externally, and quite comparable to vegetable parchment, which has been called *pergamyn*. But *pergamyn* is not a cellulose hydrate, but rather a cellulose boiled to the condition of boiled (sodden) rags, and from a chemical view-point is clearly distinguished from the hydrate, which is vegetable parchment by the reagents iodine and potassium iodide; the parchment alone, a cellulose hydrate, becomes blue.

Up to now we have only spoken of wood and of the cellulose extracted from it. Without going farther, other problems present themselves when the different ligneous essences are considered as subjects for research: how to recognize the different kinds of wood and the celluloses they yield; the ever-green woods such as pine and fir, and the wood with decaying foliage, of which those chiefly used are the poplar, the birch, and the beech. Every kind of cellulose produced from these different woods should be clearly distinguished.

Besides wood is not the only raw material which produces cellulose. Cellulose can be extracted from other ligneous fibres.

particularly herbaceous plants. In Germany it is made from wheat and rye straw, in England and in the rest of continental Europe from esparto grass or alfalfa. This last can be disintegrated by a fermentation analogous to the steeping of flax, but the soda process is principally used. This process only is applied to straw. When the sulphate process is used, *i.e.*, the process when the work of sodium hydrate is completed by sodium sulphate, a 42 per cent. yield of a cellulose is obtained, which from its reactions should be considered as an oxycellulose, although it is not as yet very thoroughly understood. In spite of its comparatively weak mechanical resistance as compared to bisulphite cellulose, it furnishes a raw material very applicable for manufacturing letter paper. The problem of the residual lyes is the same as in the case of boiling wood with soda. Really, in the recovery of the alkali, the most interesting question is that of the noxious fumes; but the lyes also doubtlessly contain substances of considerable alimentary value, and further, substances which are gelatinous and have a certain coloring power, of such a kind as to offer one more reason for attempting to utilize these lyes in an advantageous manner.

The considerable development of the manufacture of cellulose, both from wood and straw, gives rise to the fear of a dearth of raw materials in the future. Thus the German cellulose factories are already treating wood brought from the shores of the White Sea. If the devastation of the forests should progress rapidly in the northern countries, the cellulose industry will be stopped by the want of raw materials. There is so much the more reason that our country should be able to furnish the quantity of wood demanded by the industry. Besides, the available quantity of straw is very limited. The indigenous plants which should furnish large quantities of fibre suitable for paper making are not at our disposal, for the hope of converting turf into a fibre utilizable for paper has proved deceptive. Since considerable capital has been swallowed up in attempts to effect this, it would appear prudent to give it up completely. In any case there still remain reeds; but only for our Austro-Hungarian neighbors. In fact it seems that in the delta of the Danube and in the lower Danube region, reeds are found from which there can be successfully extracted a cellulose analogous to that from straw. In any case it must

not be forgotten that the quantity of available fibre here is not very large. Hence for the future of paper-making in Germany, we must look to our colonies.

For the moment let us imagine that plants could be treated where they grow, in some way so as to decrease as much as possible the dead weight for transportation, and could be sent to Europe in a half-prepared condition. According to information from an English origin, in Burmah alone there are 60,000 square miles covered with bamboo jungles close to navigable rivers. Granting the rapid growth of these plants, it has been calculated that an area of 16 square miles would be enough to furnish the raw material necessary to make 100 tons of paper per week. It follows that Burmah, that small part of India, would alone suffice to furnish as much cellulose as the whole world demands. The scarcity of wood, however, is not yet so pressing that there is any need to introduce the cellulose manufacture in countries with a murderous climate, to consume enormous capital, and to expose it to the difficulties of considerable hand-labor. From this point of view America is much better off. Putting aside the fact that in this country it is still possible to devastate the forests on a large scale, instead of having recourse to the creation of a new industry, the short fibres which adhere to the cotton bolls can be used, and the residues and waste of raw cotton, about 600,000 tons of raw material; further, there is still available about 22,000,000 tons of cotton stalks, which have been hitherto considered of no value and are buried by the plow every year. At the same time, and in an analogous manner, the maize stems, wild hemp, marsh herbs, and wild rice are wasted. Some of these American sources already feed the German paper industry. Thus the factories at Bremen treat cotton, utilizing the fibres sticking to the cotton bolls and using them to prepare a product commercially sold under the name of *Virgo fibre* (thread).

Another very important industry, and to an extent closely allied to the cellulose industry, has also developed greatly: that of artificial silk. That, too, uses cellulose as the raw material. The total natural silk in the world is estimated at 50,000,000 kilograms (110,000,000 pounds) worth \$350,000,000; the production of artificial silk has reached 5,000,000 kilograms (11,000,000 pounds) worth \$20,000,000. Although

the use of natural silk has not yet diminished in favor of artificial silk, the foregoing figures show the growing importance of this new and quite young industry; quite young for it only began in 1880.

In the beginning cotton cellulose was the only thing they dreamed of using. This cellulose was treated with nitric ether (*sic. nitric acid?*), the product thus obtained was dissolved in a mixture of alcohol and ether, and the solution transformed into thread, which, by the use of reducing agents, such as calcium sulphide, was rendered unflammable. Soon, however, a second process came into use, which consisted in dissolving cotton cellulose in a cupro-ammoniacal solution, spinning this solution, and coagulating it by means of acids or bases. A third process, the production of viscose silk, has lately been added to the preceding ones.

But the development of this industry has not answered to its early promise on account of the high price of its raw materials, viz.: wood cellulose, carbon bisulphide, and soda lye; in fact the manufacture is much too difficult. It is only after 12 years of efforts that the scientists Cross and Bevan succeeded in making the process practical, and thoroughly mastered what they termed the "maturing" of the viscose. Really, when the three processes were yet in the midst of their development, they encountered a fourth and most serious competitor which came on the scene, although it is true that no marketable product of this process seems yet to have appeared in commerce, that is, silk from cellulose acetate.

While the three kinds of artificial silk mentioned earlier contained only cellulose, regenerated in different ways, in this case the finished thread contained an acetic ether of cellulose. This ether is insoluble in water and, moreover, preserves its mechanical (physical) resistance in presence of water, a quality to which the other artificial silks cannot pretend, except in a very limited degree. The artificial silks from nitrocellulose, from ammoniacal copper, and viscose silk are in themselves less substantial than natural silk, but when they are damp they lose a great deal of the little resistance they possess. This drawback, of preponderant influence, has already made itself felt in dyeing, but it makes itself felt still more during weaving, when the fibres come in contact with water or with damp air.

Silk from the acetate does not suffer from exposure to humidity. At first great difficulty was experienced in dyeing because aqueous solutions of coloring matters would not penetrate the fibre, but by using agents which swelled the fibre these difficulties were overcome. There is no need to enlarge on this subject because a short time ago Professor Knævenagel enlightened us as to the tinctorial properties of acetylcellulose in a very interesting lecture, with experiments, that he gave at Heidelberg at the reunion of the Association of South German Chemists.

All that has been previously said as to the chemical difficulties applies also to the conditions in which the acetate is produced. The use of acetic anhydride and a little sulphuric acid at the same time, results in the very great instability of the ethereal solutions thus obtained, and this causes more or less fragility of the threads or films which have been produced. Now these difficulties are avoided by various methods. In Knoll & Co.'s patents we find sulphuric acid replaced by benzolsulphonic acid as suggested by Knævenagel, as well as the addition of neutral salts to the alkaline salts used as regenerators. The effects of these modifications are: to stop hydrolysis which is not desirable, to prevent the destruction of celluloses of large molecular weight, and to obviate any ulterior modification of the physical properties of the product obtained. Aside from the solution of this problem, an appropriate solvent has also been sought for several years. Now acetone and acetic ether have become the regular solvents, while formerly no one dreamed of using anything but chloroform, glacial acetic acid, or analogous liquids, which made the practical use of cellulose acetate very difficult. Thanks to the kindness of Professor Knævenagel and the firm Messrs. Knoll & Co., I am enabled to show you here some samples of cellulose acetate and of artificial horse-hair, the production of which is still in the experimental stage. At the same time, I can show you, thanks to the kindness of the color manufacturers, Messrs. Frederic Bayer & Co., a fine collection of sensitive preparations with a cellite (cellulose acetate) base. As you have already learned at our general meeting at Jena something of cellite films, it appears that the problem of the inflammability of kinematograph films (hitherto made of celluloid) has been entirely solved.

The destruction of the cellulose molecule pushed too far during the etherification referred to above, is the cause of great difficulties, not only in the production of acetate, but also in that of Chardonnet's Glanzstoff silks, and of viscose silk, which should be included; in fact, during the regeneration of cellulose, not only cellulose but also a cellulose hydrate is produced. This hydration must be considered as the reason for the weak mechanical resistance of the thread in the presence of water. According to Eschaliér, this inconvenience can be avoided by treating viscose with formaldehyde in acid solution. Eschaliér is convinced that formaldehyde induces the spontaneous reconstruction of the molecule previously destroyed. According to his figures, the mechanical resistance of viscose silk thus treated is increased in a considerable degree. There still remains the question whether, in spite of the increase in solidity, the elongation (extension) is still sufficient; for it is the low value of these two properties which has hitherto so unfavorably distinguished artificial silks from natural silks. The most important problem in the industry of artificial silks that still remains to be solved is that of endowing them with these two properties.

There is still to be mentioned the complication of questions relating to cellulose hydrates, found in Knecht's recent work on mercerized cotton. He shows that the absorbent power of cotton differs remarkably according to whether during mercerization, it has not been dried at all, or has been dried; and if dried, whether this has been done at the ordinary temperature or at 100° C. Hence different methods of drying give rise to different hydrates. Also Berl states that if cotton is heated in a current of inert gas at a high temperature, it undergoes polymerization which exerts a favorable influence on the properties of the resulting nitrocelluloses.

These considerations make it sufficiently clear that in the cellulose industry and its allied industries, in spite of the numerous isolated observations, the characteristics of cellulose or the celluloses are very imperfectly known from the chemical point of view. We do not even know the constitution of the cellulose of cotton, which may be taken as the type, and still less of its derivatives—the cellulose hydrates, the hydrocelluloses, and the oxycelluloses. We can only form a vague idea of

these bodies. If the cellulose industry is to continue to progress, it is absolutely necessary that a systematic study be made of all the bodies included in the above category.

An advance in the study of their constitution can generally be effected either by the synthesis or the analysis (destruction) of these bodies. There can be no question at present of constructing a molecule of cellulose, but by destroying an apparent molecule, a certain enlightenment seems to have been obtained. By making decomposition products, we have only a very superficial idea of the cellulose hydrates, but we already know a little more about the hydrocelluloses; we specially know, thanks to Tollens, that when the oxycelluloses are heated with milk of lime (calcium hydrate) they yield dioxybutyric acid and isosaccharic acid; we know that they form sugar by hydrolysis in an acid solution, and by the same method a body representing an intermediary state of transformation between sugar and cellulose—cellobiose.

The theory based on the figures representing these decompositions would be very fruitful, and would be still more so if the researches were made under similar conditions on the large number of celluloses that can be isolated from wood and herbaceous plants. It is highly probable, however, that resort must be had to new methods of research. The future will tell us if these new methods should to some extent encroach on the boundaries of the chemistry of the colloids. In spite of the splendid results found in the domain of the chemistry of the inorganic colloids, it seems as if the organic colloids, cellulose amongst them, would escape from disclosing the secrets of their constitution like so many colloidal substances. Whether it be by purely chemical methods, or by physicochemical methods, there is no doubt, in any case, that those who devote themselves, regardless of the labor, to such serious experimental researches, will have greatly accelerated the progress of the chemistry of cellulose as well as that of pure science, and that the progress of the cellulose industry will likewise be facilitated.

COMPARISON OF THE DIFFERENT METHODS OF MEASURING THE DI-ELECTRIC CONSTANT.

BY

M. PAUL FLOQUET.

(Translated from *Comptes rendus*, cli, No. 11, by W. J. Williams, F.I.C.)

THE di-electric constant is measurable by very diverse methods, generally giving discordant results. This is explicable, when it is considered that the different formulas used for this purpose are based on the supposition that a perfect di-electric is used. Since M. Malclès has shown that the hard paraffin extract of ozokerit has no residual charge at the ordinary temperature, has lost all appreciable conductivity, and therefore seems to be a perfect di-electric, I have sought to obtain really concordant values by applying different methods of measuring the di-electric constant to this paraffin.

After proving the absence of any residual charge and of conductivity in the paraffin used, at first I chose an arrangement which enabled me to compare the values of the di-electric constant obtained by two different static methods at the same time. Between the two brass cylinders of one of Messrs. Bichat and Blondlot's absolute electrometers, a hollow cylinder of paraffin is placed, suspended from the beam of a balance. This cylinder has the same axis as the cylinders of the electrometer and its lower extremity is placed almost at mid-height of the space common to the two cylinders.

By using the balance of the electrometer, I measure the attraction F' of the movable metallic cylinder; on the other hand by the help of the second balance I determine the attraction F'' of the paraffin cylinder.

I then take out the paraffin, and for the same difference of potential V , determined by a very sensitive gauge, I find the attraction F of the movable cylinder of the electrometer.

The values of F and F' on one hand, and of F and F'' on the other, enable us to find the value of the di-electric constant K . The following formulas, easy to calculate, are used:

$$F = \frac{V^2}{4} \frac{1}{L \frac{R}{r}},$$

$$F' = \frac{V^2}{4} \frac{1}{L \frac{R}{r} - \left(1 - \frac{1}{K}\right) L \frac{R'}{r'}},$$

$$F'' = \frac{V^2}{4} \left[\frac{1}{L \frac{R}{r} - \left(1 - \frac{1}{K}\right) L \frac{R'}{r'}} - \frac{1}{L \frac{R}{r}} \right],$$

where R is the radius of the exterior cylinder of the electrometer, r the radius of the interior cylinder, R' the external radius of the paraffin cylinder, r' its internal radius. It should be noticed that $F'' = F' - F$, and if F is known, an absolute value for the difference of potential used can be found.

The measurements were first taken with a constant difference of potential V . Under these conditions there occurred a phenomenon which disturbed the measurements, although the paraffin used might be considered as a perfect di-electric.

Immediately after the establishment of a constant field in the electrometer, a progressive diminution of the attractions F' and F'' is observed. I have proved that this diminution is due to the appearance, on the surfaces of the paraffin cylinder, of charges of the same sign as those of the opposite armatures: the charge on the internal surface being of greater absolute value than that of the external surface. The speed with which the attraction diminishes is very variable from one day to another. Observation of the spontaneous discharge of an electroscope placed in the laboratory has enabled me to ascertain that the perturbation was greater the more rapidly the electroscope lost its charge. Accordingly the parasitical charge of the paraffin cylinder can be attributed to the existence of electrified centres in the air of the laboratory.¹ These are displaced by the action of the electric

¹ Langevin: Bulletin des Séances de la Société de Physique, 4th fasc., 1904, p. 67.

force and deposit themselves on the surface of the paraffin. Analogous phenomena have been pointed out by Messrs. Crémieu and Malclès² who observed a progressive diminution of the electrostatic influence through an isolating plate. I have observed that brush discharges, or X-rays sent through the field of an electrometer, produce the same effect, but with much greater intensity.

Days occur when the atmospheric ionization is so weak that the paraffin does not acquire any appreciable charge. At such times precise measurements can be taken. It is useful to remark that the error introduced by atmospheric ionization into the measurements of the di-electric constant by static methods, is in a sense inverse to the error caused by conductivity or by residual charges.

The same measurements with the same apparatus were again taken, using alternative potentials with a frequency of 50. In this case the values of the attractions are strictly invariable. The results deduced agree with those obtained by the static method on those days when the effects of the atmospheric ionization are negligible.

Measurements were made with cylinders of different dimensions.

Table I gives the results obtained for cylinders of different radius.

TABLE I.

Potentials, volts	Attraction in milligrammes				Dielectric constant determined by	
	<i>F</i>	<i>F'</i>	<i>F''</i>	<i>F'-F</i>	<i>F'</i>	<i>F''</i>
5300.....	790	955	165	165	2.288	2.288
18900.....	1005	1215	211	210	2.290	2.302
21700.....	1208	1460	255	252	2.285	2.314

$R = 48.70$ mm.; $r = 17.45$ mm.; $R' = 37.71$ mm.; $r' = 27.52$ mm. The values of K were determined approximately to the one-hundredth. It is obvious they are concordant. Further,

² V. Crémieu et L. Malclès: Comptes rendus, Nov. 14, 1904, p. 790; and L. Malclès, Thèse de Doctorat.

they agree with the value 2.30 as determined by Macles³ using a static method.

Then I used a completely different method, which consists of measuring the ratio n of the speed of propagation of the Hertzian waves in air and in paraffin. Blondlot⁴ has shown that in the case of Maxwell's relation, $n^2 = K$, is rigorously applicable. The measurements were made by observing the retardation effected in the waves during their passage through a copper wire 179 cm. long, sunk in paraffin. I used the method which Gutton⁵ applied to the determination of the di-electric constant of ice. Working with different lengths of wave, the results shown in Table II were obtained.

TABLE II.

Length of wave, cm.	Retardation, cm.	Index of refraction	Di-electric constant
36.....	92	$n = 1.514$	$K = n^2 = 2.292$
50.....	91	$n = 1.508$	$K = n^2 = 2.275$
100.....	91	$n = 1.508$	$K = n^2 = 2.275$

The values of K were again determined approximately to the one-hundredth. They agree with those given by the method of slow oscillations and the purely static method.

It is again obvious that, with the paraffin used, the dispersion of the electromagnetic waves appears very slight and does not introduce any notable difference between the values of the di-electric constant whether relative to slow oscillations or to very frequent oscillations.

³ L. Macless: Thèse de Doctorat.

⁴ R. Blondlot: Comptes rendus, 1892, No. 5, cxv, p. 225.

⁵ C. Gutton: Comptes rendus, 1900, No. 5, cxxx, p. 1119.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, October 19, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Oct. 19, 1910.

President Mr. WALTON CLARK in the Chair.

Additions to membership since last report, 9.

Mr. E. E. Watson, Factory Inspector, Herring-Hall-Marvin Safe Company, Hamilton, Ohio, presented a communication on "Recent Advances in the Construction of Fire and Burglar-Proof Safes."

The speaker gave an interesting account of the progress made in the construction of locks and the building of burglar and fire-proof safes. He described the various kinds of locking devices from the latch lock to the most recent form of changeable-key lock. Mention was made of the various types of safes constructed during the past century, special attention being given to those in use to-day. At the close of the paper the thanks of the meeting were extended to the speaker and the subject was referred to the Committee on Publications. Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Proceedings of the Stated Meeting held Wednesday, October 5, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 5, 1910.

Mr. THOMAS SPENCER, in the Chair.

The following report was presented for final action: (No. 2480) Reeves Variable Speed Transmission. (Advisory, adopted.)

No reports were presented for first reading.

R. B. OWENS,
Secretary.

SECTIONS.

Electrical Section.—A meeting of the Section was held on Thursday evening, October 6, 1910, at eight o'clock; fifty members and visitors present. The meeting was called to order by Mr. Thomas Spencer, Chairman of the Section. In the absence of Mr. Joseph Appleton, who was unavoidably detained in Chicago, his paper on "Some Recent Problems in Storage Battery Engineering" was read by the Secretary of the meeting. The use of the storage battery in modern industrial establishments was described and results of its operation as an adjunct to power-generating plants were shown.

The subject was discussed by Dr. Goldsmith, Mr. Tracy, the Chairman, and others. Adjourned.

ALFRED RIGLING,

Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday, October 13th, at eight o'clock. Dr. W. J. Williams, temporary Chairman. Eighty members and visitors present.

After reading of the minutes of the previous meeting, the Chairman introduced Mr. J. A. P. Crisfield, Engineer of Construction of the United Gas Improvement Company, Philadelphia, who presented a paper on the "Mechanical Engineering Problems in Illuminating Gas Works." The speaker referred to the most important problems which the mechanical engineer is compelled to solve in the modern plant of a gas works. The subject was illustrated by numerous lantern slides.

After a brief discussion the thanks of the meeting were extended to the speaker.

ALFRED RIGLING,

Acting Secretary.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, October 20, 1910, at eight o'clock.

The meeting was called to order by the President of the Section, Prof. A. E. Outerbridge, Jr.

Fifty members and visitors were present.

The Chairman introduced Mr. Henry Souther, President of The Souther Engineering Company of Hartford, Conn., who presented a communication on the "Selection and Treatment of Alloy Steels for Automobiles." The speaker called attention to the necessity of selecting steels which will do most efficiently the work for which they are intended. The various grades of steel were described and reference was made to their composition.

After a brief discussion Prof. Outerbridge presented his annual address as President of the Section on the "Integrity of Tests of Metals." As this has already been printed (see this JOURNAL, clxx, 206) it was read in abstract only. Lantern slides of cross-sections of various metals and test-bars were shown and described and specimens of test-pieces were passed among the audience for examination.

The thanks of the meeting were tendered to the speakers and Mr. Souther's paper was referred to the Committee on Publications. Adjourned.

ALFRED RIGLING, *Acting Secretary.*

FRANKLIN INSTITUTE

MEMBERSHIP NOTES.

Elections to Membership.

LIFE.

EDW. V. McCAFFREY, Manufacturer, Fifth and Berks Sts., Phila.
JAMES G. DAVIS, Mech. Engineer, The U. G. I. Co., Broad and Arch Sts., Phila.

RESIDENT.

JOHN MORRIS WEISS, Chemist Barrett Manufacturing Co., Frankford, Phila.
WALTER DILKS, 1102 Chestnut St., Phila.
R. NORRIS WILLIAMS, 8124 St. Martin's Lane, Chestnut Hill.
J. A. STEINMETZ, Iron and Steel, Central Trust Co., Fourth and Market Sts., Phila.
WILLIAM H. BALLS, Teacher, 5120 Greene St., Germantown, Phila.
JOSEPH S. HEPBURN, Chemist, 1833 Chestnut St., Phila.
S. PRICE STEVENSON, Manufacturer, Chester, Penna.
WARNER G. EARNSHAW, Bituminous Coal, Harrison Bldg., Phila.
NORMAN MACBETH, Illuminating Engineer, Weightman Bldg., Phila.
HENRY A. GARDNER, Chemist, Paint Manufacturers Assoc., 3500 Grays Ferry Road, Phila.
JOHN J. GIBSON, Elec. Engineer, 115 So. Broad St., Phila.
JOSHUA A. PEARSON, Purchasing Agent, The U. G. I. Co., Broad and Arch Sts., Phila.
E. R. KNOEDLER, Asst. to Gen. Manager, Welsbach Co., Gloucester, N. J.

NON-RESIDENT.

ENRIQUE CRUCHAGA OSSA, Calle de Castro No. 49, Santiago de Chile, South America.
L. AKESSON-AMREIN, Manufacturer, Zurich, Switzerland.
GEORGE C. REESE, Manufacturer, 247 East Twenty-first St., New York City, N. Y.

ASSOCIATE.

ANDREW W. HILL, Steam Heat and Ventilation Estimator, 1917 South Broad St., Phila.
CHARLES HUBSCH, Draughtsman, 1515 W. Passyunk Ave., Phila.

Changes of Address.

- M. DE TEIVE E. ARGOLLA, Caixa Postal 226, Bahia, Brazil.
 FRANK HEPBURN, care British Vice-Consulate, Mutual Life Bldg., Jacksonville, Fla.
 FRANK ANDERSON, 468 Twelfth East St., Salt Lake City, Utah.
 HIRAM W. HIXON, 251 So. Forty-first St., Phila.
 DR. E. J. HOUSTON, 1701 Chestnut St., Phila.
 RALPH D. MERSHON, 60 Wall St., New York City.
 CHARLES KIRCHHOFF, Rhineland Court, 244 Riverside Drive, N. Y.
 WILSON E. SYMONS, 900 Postal Telegraph Bldg., Chicago, Ill.
 GEORGE A. GREVEMEYER, 223 Walnut St., Phila.
 E. STUTZ, 306 West Eighty-second St., New York City.

LIBRARY NOTES.

Purchases.

- KRAHMANN, M.—Fortschritte der praktischen Geologie und Bergwirtschaft.
 OSTWALD, W.—Die Energie.
 LÜPPE-CRAMER.—Die Röntgenographie in ihrem photographischen Teil.
 VOIGT, W.—Magneto- und elektrooptik.
 RICHARZ, F.—Anfangsgründe der Maxwellschen Theorie.
 GÖCKEL, A.—Die Luftelektrizität.
 STOLZE, F.—Panoramenapparate in ihren Vorzügen und Mängeln.
 PLOTNIKOW, T.—Photochemie.
 HANN, J.—Handbuch der Klimatologie. 2 vols.
 WINKELMANN, A.—Handbuch der Physik. 6 vols.
 MÜLLER-POUILLET.—Lehrbuch der Physik. 4 vols.
 LIESEGANG, F. P.—Handbuch der praktischen Kinematographie.
 PÖSCHL, V.—Die Härte der festen Körper.
 MAURAIN, CH.—Les Etats physiques de la Matière.

Gifts.

- U. S. Coast and Geodetic Survey. Results of observations made at the Magnetic observatory at Vieques, Porto Rico, and Baldwin, Kansas, in 1905 and 1906. Washington, 1910. (From the Survey.)
 Sydney University Engineering Society, Proceedings, volume 14. Sydney, 1910. (From the Society.)
 Great Britain, Labour Department. Report on Changes in rates of wages and hours of labour in 1909. London, 1910. (From the Board of Trade, Labour Department.)
 Boston and Maine Railroad. Report 1909-'10. Boston, 1910. (From the Railroad.)

- St. Louis, Mo., Water Commissioner, Annual report. St. Louis, 1910. (From the Commissioner.)
- Illinois Bureau of Labor Statistics. 28th annual coal report, 1909. Springfield, 1910. (From the Bureau.)
- Der Ausban der Niederdruckwasserkräfte, von Adolf Ludin. Heidelberg, 1910. (From the Technical High School, Karlsruhe.)
- McGill University, Matriculation Examination results. Reports and papers. Montreal, 1910. (From the University.)
- New York State Library, Bibliography bulletin No. 4. Albany, 1910. (From the University.)
- Northampton Polytechnic Institute, Announcements 1910-1911. London, n.d. (From the Institute.)
- Western Australia Mines Department. Report on the state of mining progress in certain centres in the Marchison and Peak Hill goldfields, by A. Montgomery. Perth, 1910. (From the Department.)
- Great Britain, Labour Department. Report on strikes and lock-outs in the United Kingdom in 1909. London, 1910. (From the Board of Trade, Labour Department.)
- U. S. Brewers' Association. Proceedings of 50th annual convention. New York, 1910. (From the Association.)
- India Geological Survey. Memoirs. Palæontologia Indica, new series, vol. 3, Memoir No. 1. Calcutta, 1909. (From the Survey.)
- Illinois Geological Survey. Bulletin No. 15. Springfield, 1910. (From the Survey.)
- U. S. Geological Survey. Bulletin No. 425. Washington, 1910. (From the Survey.)
- North Carolina Geological and Economic Survey. Economic paper No. 19. Raleigh, 1910. (From the Survey.)
- Königlich-Technische Hochschule zu Hannover. Programm, 1910-1911. Hannover, 1910. (From the High School.)
- Nova Scotian Institute of Science. Proceedings and Transactions, vol. 7, part 2. Halifax, 1910. (From the Institute.)
- Lynn, Mass., Public Water Board. Annual report for 1909. Lynn, 1910. (From the Board.)
- Meteor Crater in Northern Central Arizona, by D. M. Barringer. (From the Author.)
- New South Wales. Official Yearbook 1908-9. Sydney, 1910. (From the Government Statistician.)

BOOK NOTICES.

NOTIONS FONDAMENTALES SUR LA TELEGRAPHIE. Envisagée dans son développement, son Etat actuel et ses Derniers Progres. (Du Breguet au Pollak et Virag et aux Telephotographes.) Par Albert Turpain, Professeur de Physique á la Faculte des Sciences de l'Universite de Poitiers. 180 pages, 9 x 6 inches, with 122 figures. Price 5 francs.

TELEPHONIE DU TELEPHONE BELL AUX MULTIPLES AUTOMATIQUE. Essai sur les origines et le Développement du Telephone. Par Albert Turpain. Professeur de Physique á la Faculte de l'Universite de Poitiers. 186 pages, 9 x 6 inches, paper with 123 figures. Price 5 francs. Bibliothèque de l'Elève-Ingenieur. Gauthier-Villars, Paris, 1910.

These monographs are components of a series designed for the engineer-student. The subject-matter is mainly descriptive, theoretical considerations being dwelt upon but briefly.

The work on telegraphy is treated under the divisions (1) Simple Telegraphy, relating to apparatus in present common use. (2) Rapid Telegraphy, and (3) The Future of Telegraphy.

In the work on telephony the subject is introduced with a brief history of the development of the art. The various devices and applications of the usual plant are described in detail terminating with a chapter on the relative recent Strowger automatic system.

Both volumes are fully illustrated by well executed diagrams and cuts with annotations. They should prove very satisfactory works indeed for their intended purposes.

THE TELEGRAPHIC TRANSMISSION OF PHOTOGRAPHS. By T. Thorne Baker, F.C.S., F.R.P.S., A.I.E.E. XI. 146 pages, 7½ x 5 inches, 64 figures, cloth. D. Van Nostrand Company, New York, 1910. Price \$1.25.

Although attempts at the transmission of pictures by telegraph dates as far back as the beginning of telegraphy itself, the problem has proved a difficult one and it is only within comparatively recent years that a reasonable measure of success has been attained. The author having been actively engaged in experimental work of this kind is especially qualified to carry out his purpose of collecting under one cover notes of interest relating to past experiments and recent achievements scattered in the files of the technical press. Considerable space is devoted to the description of two promising recent systems, one developed by Professor Korn, the other by the author. The work is of particular value in saving the labor of searching for original papers for information on the subject, a list of which would have materially added to the value of the book.

NOTIONS ÉLÉMENTAIRE SUR LA PROBABILITÉ DES ERREURS. Par Maurice d'Ocagne, Ingenieur de Ponts et Chaussées, Professeur à l'Ecole des Ponts et Chaussées. 27 pages, 9 x 6 inches, 2 diagrams, paper. Gauthier-Villar, Paris, 1910.

A casual glance over any of the numerous treatises dealing with the theory of probability of errors will satisfy anyone accustomed to technical reading that a study of the subject is not one to be undertaken in a trivial spirit. For that reason a serious student who might desire to learn the meaning of the formulas developed and their more simple application is often deterred from making the attempt. M. d'Ocagne's brief treatise will appeal strongly to such readers. It is a reprint of two lectures before the students of the French school of Bridges and Highways and embraces the principles of the subject as far as they may be applicable to measures of precision employed by engineers. Except in the elementary theory of probability, no attempt is made to derive the results presented and discussed at considerable length. In that respect the work is somewhat disappointing, notably in the omission of an analytical demonstration of the equation representing the probability of an error as a function of its magnitude. But a full demonstration of all the theorems embraced would many times multiply the compass of the volume and defeat the author's purpose to present briefly an outline of the subject and its applications.

LES COMPTEURS ELECTRIQUES A COURANTS CONTINUS ET A COURANTS ALTERNATIFS. Leçons Professees a l'Institut Electrotechnique de Grenoble. Par L. Barbillion, Professeur a la Faculte des Sciences, Directeur de l'Institut, avec la Collaboration de G. Ferroux, Ingenieur, Charge de Conférences a cet Institut. Paper vii + 226 pages, 7 x 4½ inches, 126 diagrams. Gauthier-Villars, Paris, 1910. Price 3 francs 0.25.

The present volume is a contribution to a series of monographs on various topics of technical interest issued under the title "Actualities Scientifiques." Although an already well-trodden field is covered, it would be difficult to find a better presentation of the subject for study or a better arrangement for reference. The general principles and component elements of modern electric meters are set forth with but a passing mention of superseded and nondescript types. The work is divided into three chapters dealing respectively with continuous-current meters, alternating-current meters, and meters of special types to meet unusual conditions, closing with an appendix containing complete specifications and tests for meters prescribed by the Electrotechnical Institute of Grenoble.

Each of the numerous types presented is treated as a separate unit and in proper sequence, a feature of undoubted merit in a text-book. There are no illustrations of actual apparatus, but the well adapted line diagrams which illustrate the subject serve a better purpose. The text in precision and deductive clearness is excellent. The demonstrations are at once ample and concise and, what is better still, convincing. The work is clearly the product of master hands in the art of elucidation.

LA MÉTALLOGRAPHIE MICROSCOPIQUE. Par L. Révillon, Ingenieur des Arts at Manufactures. 176 pages, $7\frac{1}{2} \times 4\frac{1}{2}$ inches with 24 figures, paper (Encyclopédie Scientifique des Aide-Mémoire). Gauthier-Villars, Paris, 1910. Price, paper, 2 francs 50; flexible cloth, 3 francs.

The microscopic examination of the structure of metals has in recent years become an accepted and highly valued mode of investigation in industrial technical laboratories. The appearance of a work dealing with the technic of the method as practised in the laboratories of the firm of Dion-Bouton,—a name synonymous with refinement in automobile construction,—of which the author is in charge, cannot fail to be cordially welcomed. The manipulations involved in the various operations are described in detail followed by an illustrated account of the results of examinations of many different metals and alloys illustrated by half-tone photographs. An appendix treats of the similar mode of examination without the use of the microscope and with a less careful preparation of the specimen by which means quite satisfactory conclusions may be drawn.

ELECTRICITY EXPERIMENTALLY AND PRACTICALLY APPLIED. A Book for the Beginner and for the Practical Man; Principles, Experiments, Practical Applications and Problems. By Sydney Whitmore Ashe, B.S., E.E., Author of "Electric Railways"; formerly Instructor in Physics and Electrical Engineering, Polytechnic Institute of Brooklyn. 349 pages, 12 mo., cloth. D. Van Nostrand Company, New York, 1910. Price \$2.00 net.

Anyone of usual intelligence can learn something by purely experimental teaching and a great deal if the teaching is systematically carried on. No apology is, therefore, needed for a work which covers the subject in proper order from the fundamental elements of electromagnetism to its most elaborate application to current production and the transmission of power. The primary object of the work is to meet the needs of students recruited from the ranks of manufacturing establishments who have had little or no mathematical training and to aid those of the "self-taught" type by means of the full and well illustrated descriptions. A student who masters the contents of the book will seldom be at a loss in responding to demands of practical service.

NOTES ON MECHANICAL DRAWING. Prepared for the use of students in Mechanical Engineering at the University of Pennsylvania. By Horace P. Fry, B.S. in E.E., Asst. Professor of Mechanical Drawing. 60 pages, 6×9 inches, cloth, illustrated. Printed for the University, Philada., 1910.

Mechanical drawing has been characterized a universal language by whose aid the engineer may with the greatest possible brevity direct the embodiment of his ideas into a concrete form. The definition is appropriate enough for, with its development to meet the ever-increasing needs and refinements incident to industrial progress, it has like any other language in constant use acquired a corresponding variety of shades of expression and

meaning. At the present day more is required in professional draughtsmanship than a knowledge of the principles of projection and dexterity in drawing-board processes.

Notes on mechanical drawing covers just those features that mark the difference between a draughtsman qualified to meet the requirements of the factory drawing office and the draughtsman who knows how to draw but has yet to learn the knack of making drawings of commercial value.

It contains full instructions governing the procedure which the student is required to follow in prosecuting the several courses specified, and constitutes a code of practice which might with advantage be adopted in many commercial drawing offices. The instructions are precise and emphasized by the free and commendable use of bold-faced type at critical points. In great detail the student is shown, adequately illustrated, the very things which ordinarily he is expected to devise for himself, such as arrangement of views, dimensions, size and position of legends and title, for the best effect.

It is doubtful that any topic of material consequence has been omitted and if there is any occasion to disagree with some of the methods or recommended forms, such disagreement will arise from local requirement or personal preference rather than from any real shortcoming.

The Twelve Principles of Efficiency. HARRINGTON EMERSON. (*Eng. Mag.*, xxxix, 3 etc.)—This series of articles on business organization is of the greatest interest to all business men and especially to the heads of large concerns. No abstract can give an adequate conception of its scope and tendency, but its perusal will cause every man to "stop and think."

Modern Methods of Lightning Protection. CHAS. P. STEINMETZ. (*Eng. Mag.*, xxxix, 4.)—An article of importance to those connected with institutions using electricity and especially those generating electricity. "The requirements of the lightning arrester are, that it affords a path from the line to ground at moderate over-voltage, that this path be of unlimited discharge capacity, that it afford no appreciable resistance or inductance to the discharge, and that the discharge shall not result in any disturbance of the system, which might cause high voltages and thereby damage, elsewhere, and should not produce a short circuit on the system."

Blauwater-Gas and Carburetted Water-Gas. J. VAN ROSSUM DU CHATTEL. (*Gas Lighting*, cxi, 511.)—Two plants of the same capacity, one making each kind of gas, have worked for four years in Amsterdam. The cost of carburetted water-gas is only five-sixths the cost of Blauwater-gas. About 25 to 30 per cent. of Blauwater-gas is mixed with the coal-gas and the mixture carburetted with petroleum benzine of 0.74 sp. gr. It has been found that a considerable quantity of the benzine falls out in the mains, both in summer and winter.

PUBLICATIONS RECEIVED.

Providence, R. I., City Engineer's Report for 1909. 90 pages, illustrations, tables, 8vo. Providence, City Printers, 1910.

Republica Argentina, Centenario Exposicion internacional de ferrocarriles y transportes terrestres, Buenos Aires, Mayo a Noviembre, 1910. Circular No. 24. 24 pages, illustrations, 4to. Buenos Aires, 1910.

The Chemist's Pocket Manual. A practical handbook containing tables, formulas, calculations, information, physical and analytical methods for the use of chemists, chemical engineers, assayers, metallurgists, manufacturers, and students. By Richard K. Meade, M.S. Second edition. 443 pages, illustrations, 16mo. Easton, Pa., The Chemical Publishing Co., 1910. Price \$3.00.

North Carolina Geological and Economic Survey. Economic Paper No. 20. Wood-using industries of North Carolina. By Roger E. Simmons. Raleigh, State Printers, 1910.

"World Corporation." By King Camp Gillette, discoverer of the principles and inventor of the system of "World Corporation." 240 pages, illustrations, portrait, 8vo. Boston, New England News Co.

U. S. Bureau of Standards. Circular No. 7. Pyrometer testing and heat measurements. Fourth edition, 16 pages, 8vo. Washington, Department of Commerce and Labor, 1910.

U. S. Bureau of Standards. Note on the temperature scale between 100° and 500° C. By C. W. Waidner, Physicist, and G. K. Burgess, Associate Physicist. Reprint No. 143. [From Bulletin of the Bureau of Standards, vol. 7, No. 1.]

National Association of Cotton Manufacturers. Advance copies of papers to be presented at meetings. 12 pamphlets, illustrations, portrait, 8vo. Boston, Association, 1910.

U. S. Hygienic Laboratory, Bulletin No. 67, June, 1910. The solubilities of the pharmacopœial organic acids and their salts. By Atherton Seidell. 98 pages, illustrations, 8vo. Washington, Treasury Department, 1910.

U. S. Coast and Geodetic Survey. Results of Observations made at the coast and geodetic survey magnetic observatory at Vieques, Porto Rico, 1905 and 1906. By Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 110 pages, 4to. Results of observations made at Baldwin, Kansas, 1905 and 1906. By Daniel L. Hazard, Computer, Division of Terrestrial Magnetism. 107 pages, 4to. Washington, Department of Commerce and Labor, 1910.

Michigan College of Mines. Graduates, June, 1910. 118 pages, 12mo. Year-book, 1909-1910. 134 pages, 12mo. Views of the College, narrow 16mo. Houghton, Michigan. Published by the college, 1910.

Russian Turkestan and its Products. By N. J. Malahowski, Ph.D. 11 pages, illustrations, map, 8vo. St. Petersburg, "Journal of Finance," 1910.

Link-Belt Company. The Peck carrier, patented December 25, 1900, for coal, coke, ashes, cement, sand, stone, ore, and other materials. Book No. 81. 96 pages, illustrations, 8vo. Philadelphia, Link-Belt Company, 1910.

CURRENT TOPICS

The Menne-Oxygen Melting Process. (*Iron Age*, lxxxvi, 8.)
—The equipment included in contracts for the use of the Menne process does not cover the tanks of oxygen and coal gas. These are furnished by the Linde Air Products Co. When the tanks are owned by the furnace company the cost of oxygen and coal gas is about 2 cents per cubic foot, much less than when the process was first demonstrated in the U. S. Experience has shown that two tanks of oxygen and one of coal gas will open a frozen tap-hole, cinder notch or tuyere in a few minutes. Two men are necessary to operate the apparatus.

Koenig's Theory of Ripple Formation in Kundt's Tube. J. ROBINSON. (*Phil. Mag.*, xix, 476.)—Referring to previous experiments which were in fair agreement with Koenig's theory as to the ripple formation, the author now develops the theory by extending it to the case in which the velocities concerned are different, w_1 and w_2 , instead of being identical, w_0 . It is then shown that the change in the result is simply the substitution of w_1, w_2 for w_0^2 . Comparing this theory with the experimental results gives a good quantitative agreement.

Production of Natural Gas. H. A. DANNE. (*Met. and Chem. Eng.*, viii, 412.)—The entire output of natural gas in the West Virginia oil fields is estimated at 1300 million cub. ft. per day, of which about 300 million cub. ft. are wasted. The thermal efficiency may attain as much as 1134 B. T. U. per cub. foot, but after compression of the gas it falls to about 900 B. T. U. owing to the deposition of liquefied hydrocarbons. It is employed for power purposes, zinc smelting, and the manufacture of glass, bricks, pottery, electrodes and lamp-black. Judging from the fact that the oil and gas are accompanied by coal and salt water, and that the pressure of the gas is nearly always affected by seismic disturbances, the author considers that these hydrocarbons are generated from natural carbonaceous deposits, by the earth's interior heat brought into proximity to these deposits by seismic disturbances; that they are still being generated under enormous pressure, and that on the release of some of the pressure, and consequent changes in the temperature of the hydrocarbons, some of the constituents are deposited in the dips of the strata and in the pockets known as oil-bearing pools.

Solubility of the rare Gases in Water. A. V. AUTROPOFF. (*Proc. Roy. Soc.*, A.38, 474.—The solubility of xenon, krypton, argon, neon and helium in water was determined at temperatures from 0° to 50°C. The solubility rises with the increase of the atomic weight. At 20°C. the solubilities are He 0.0138; Ne, 0.0147; Ar., 0.0379; Kr., 0.0670 and 0.0788 (the reason for this difference in values is not known), Xe, 0.1109. The solubility of xenon is greater than that of any other gas, which does not form a compound with the solvent. In the case of all the rare gases, there is a distinct minimum of solubility. The minimum for xenon and argon lies at 40°C; for krypton between 30° and 40°C; for helium at 10°C; and for neon probably at 0°C.

Silicon Steel. G. A. BISSET. NAVAL CONSTRUCTOR, U. S. N. (*Iron Age*, lxxxvi, 8.)—This article will well repay careful perusal, as it gives a careful resumé of tests to show its superiority over other kinds. Among other things it is stated that high silicon steel was largely used in the construction of the Mauretania and Lusitania, the requirements being,—ultimate tensile strength 74,000 to 85,000 pounds per square inch; elongation in 8 inches, 18 per cent. The U. S. naval requirements are: Minimum tensile strength and elongations of 60,000 pounds and 25 per cent.; and 75,000 pounds and 17 per cent. for medium steel. Manufacturers have found that the requirements for high tensile steel can be met much more readily by high silicon than by high carbon steel.

Widmanstätten's Figures. N. BELAIEW. (*Révue de Métall.*, vii, 510.)—In certain steels which had been cooled extremely slowly sections were found to show Widmanstätten's figures as clearly as many meteorites. The author considers that the first crystallization from a molten steel is octahedral iron, and that when the cooling is extremely slow these octahedra have time to assume the same orientation. During cooling after solidification, secondary crystallization sets in, and lamellæ are formed in four directions in the octahedron. According as the section taken is parallel to the face of the related cube, to the octahedron, to the dodecahedron, or at an angle with any one or all of these, the crossing of two sets of lamellæ at right angles, of three sets at 60°, or of different systems, both cut at an angle is seen, and this it is which constitutes Widmanstätten's figures. These figures therefore are not peculiar to nickel-iron alloys, but should also appear in carbon steels, the behavior of which on cooling is generally similar to that of the nickel alloys. Osmond has observed a similar structure in Swedish iron, very slowly cooled, and martensite is probably a case of the same structure, of very small dimensions, and modified by the various orientation of the original octahedra. Such a structure is characteristic of overheated steels, and is dangerous from a mechanical point of view.

Sodium Carbonate as an Oxidizer. E. DEISS. (*Chem. Zeit.*, xxxiv, 781.)—When finely divided silicon, tungsten, molybdenum, titanium, or such alloys as ferrotitanium, ferrosilicon, phosphor-iron, etc., are strongly heated with sodium carbonate, the metal becomes oxidized and carbon monoxide is evolved. This is found to offer a convenient method of attacking many metals and alloys which are dissolved only with difficulty by acids. The addition of magnesium oxide to the sodium carbonate renders it more effective, especially for chromium and its alloys, and prevents fusion of the mass. The carbon monoxide is allowed to burn as evolved, in order to avoid the possibility of reverse action.

Leaning Tower of Pisa. (*Eng. Record*, lxii, 6.)—According to the findings of a Royal Commission appointed to investigate the present condition of this tower, instead of being supported on a massive foundation, it rests on a ring-shaped masonry base, with an inner diameter of 24 ft. 3½ in., exactly the same as the inside diameter of the tower. The tower is about 177 ft. high, and in 1829 is said to have been 14 ft. 5 in. out of plumb; since that time its inclination has been increased by an additional 0.0055 ft. per foot of its height. In 1834 an earthquake caused a deflection of about 5 inches.

The World's Production of Coal in 1908. PROF. R. A. S. REDMAYNE. (*Iron Age*, lxxxvi, 9.)—The total world's product was about 1068 million tons:

	Million tons
Great Britain and her colonies produced.....	306
United States of America produced.....	377
Germany produced	215
These three countries produced.....	898
Leaving for the rest of the world.....	170

Principles of Running Balance. (*Amer. Mach.*, xxxiii, 32.)—An instructive and carefully prepared article, well worth the attention of machinists. Its contents are summarized as follows:

All rotating parts of high-speed machinery should be running balanced. A part in running balance will also be in standing balance. A part in perfect standing balance may be very far from being in running balance. The operation of standing balancing may be a detriment rather than a benefit to high-speed machine parts. A part in running balance at one speed will be in running balance at all other speeds, providing it does not distort from centrifugal action. Exact symmetry of form is no guarantee of running balance. High-speed parts should be so designed that they will not distort if rotated free at any speed at which they may run in use, and thus destroy a condition of running balance.

Absorption of Iodine by Solid Substances. M. GUICHARD. (*Comptes rendus*, cli, 236.)—Silica, both natural and calcined; alumina, calcined at 600°C .; magnesia, calcined at 1025°C .; and glucina all absorb iodine in quantities inversely proportionate to the degree of calcination. The differences in absorption are due to the shrinkages of the interspaces between the particles, and the cessation of absorption probably marks the disappearance of these interspaces and corresponds with the maximum density of the substance.

Chemical Standards for Iron Castings. JOHN J. PORTER. (*Amer. Mach.*, xxxiii, 32.)—This article will repay careful perusal. It may be summarized as below.

Cast-iron treated as an alloy, and the effect of the various ingredients present in the metal, or used in making the required mixtures. The physical properties of the metal and its behavior at different temperatures. The classification of castings, and the chemical composition of iron castings as used for various purposes; with a suggestion as to the best mixture to use for numerous purposes to which iron castings are put.

Design of Centrifugal Pumps. A. BORSODY. (*Amer. Mach.*, xxxiii, 39.)—This paper deals with the losses occurring in centrifugal pumps, their analysis and steps taken to reduce them. The principal losses in centrifugal pumps are well recognized, and by careful analysis they can be separated and the design regulated so as to produce the highest efficiency. For high heads, requiring high peripheral speeds, a diffusion-ring is employed, constituting a turbine pump. The diffusion-ring contains passages which split up the water from the impeller into streams, gradually transforming its velocity into pressure and reducing the whirlpool losses in the casing. A special construction described for surrounding the impeller with air, instead of water, so as to cut down the side friction, which is one of the principal losses in a centrifugal pump.

These principal losses are:

1. Side friction of impellers—called the rotor friction.
2. Hydraulic friction losses in the stationary parts of the pump.
3. Losses in the whirlpool chamber and losses at the periphery of the impeller.

Germicidal Value of Thymol. E. W. SCHMIDT. (*Zeit. Phys. Chem.*, lxxvii, 412.)—Thymol has been used as an antiseptic and disinfectant especially in physiological experiments on digestion. The author examines its value in this direction. Experiments were made with albumin, peptone, fibrin, organisms and enzymes in the presence of saturated thymol water. All experiments were made at a temperature of 25°C . which is the most favorable to putrefac-

tive organisms. No difference could be found in the digestive or putrefactive actions whether the experiment was made in the presence or absence of thymol. Hence the conclusion is that thymol has no power to inhibit bacterial growth and is of no value as an antiseptic or disinfectant.

Action of Metallic Contacts on a Filings Coherer. B. SZILARD. (*Comptes rendus*, cl, 1670.)—The author finds that a filings coherer is very much more sensitive when the end of the coherer (which is earthed in the usual arrangement) is connected to one terminal of an alternating-current system, the other alternating-current terminal being connected to earth. He finds that a coherer connected in this manner is affected when a metallic rod set up as sending antenna, is simply touched by a piece of metal held in the hand. This action is obtained over 150 cm. The contact between the two pieces of metal must be very light and between points. The metals brought into contact may be the same or may differ. The maximum distance at which the effect is obtained depends upon the metals used.

Carbonization of Rubber by Mercury Vapor. W. VON BOLTON. (*Zeit. Elektrochem.*, xvi, 667.)—Mercury vapor decomposes volatile hydrocarbons, chloroform, carbon tetrachloride, carbon bisulphide, carbon dioxide and hydrogen sulphide with separation of carbon or sulphur. This reaction does not occur with liquid mercury, even at boiling temperature, but only by the monatomic vapor. Amalgams seem to produce the vapor more rapidly than pure metal, probably on account of their larger surface, but the action is noticeable in presence of mercury heated to 100°C. for about three weeks. Sulphur accelerates the action, selenium and tellurium retard it. Traces of moisture are requisite. If mercury vapor attacks pure non-vulcanized rubber, no carbon is separated but the rubber becomes hard and brittle and traces of mercury can be found in it. The carbon separated in ordinary experiments is found to contain small microscopic crystals of diamond.

The Inventor of the Black-Ash Furnace. W. RAMSAY. (*Chem. News*, cii, 69.)—In the correspondence of Dr. Joseph Black a letter to him from a Mr. George Golder was found, bearing the date of March 19, 1782, advising Dr. Black that Mr. Golder was sending him a sample of ashes made by Messrs. Collison and Co., London, with a copy of Collison's specification for making mineral and vegetable alkali, by the use of a reverberatory furnace. Dr. Black examined the ash and found it about 50 per cent. stronger than the best Alicant barilla, and about seven times the strength of kelp. The patent granted to Le Blanc for the process of manufacturing sodium carbonate and sodium hydrate was dated Sept. 23, 1791, and is therefore nine years later than Collison's patent.

Ultramarine. J. HOFFMANN. (*Chem. Zeit.*, xxxiv, 821.)—On consideration of the numerous investigations of this product the author concludes that the homogeneous character of ultramarine and the fact that changes in the constituent oxides are often unaccompanied by any essential alteration in color, are best explained by regarding it as a dilute solid solution containing besides alumina, boric anhydride, silica, and oxides of sulphur, dissociation products of thiosulphates, and probably sulphur itself.

New Phosphate Deposits. (*Board of Trade Jour.*, Aug. 25, 1910.)—An important find of phosphate deposits has been made at Safage, about 260 miles from Suez, on the western coast of the Red Sea. This deposit has been carefully examined and work will soon commence.

Examination of Steels by Corrosion. M. F. CLOUP. (*Rev. de Métall.*, vii, 605.)—A method is described for the examination of manufactured steel (forgings, etc.) in which the polished metal surface is treated either with a 4 per cent. solution of picric acid in absolute alcohol, or, as a less active reagent, with an iodine solution of 10 parts of iodine and 20 of potassium iodide, in 100 of water. By the action of the solvent, the lines of flow induced in the metal by the mechanical treatment become visible to the naked eye; and thus it is possible to discover the method used for the manufacture of the piece under examination. The effects due to mechanical treatment are generally easily distinguishable from initial defects in the metal and from changes induced by heating; in doubtful cases the microscope can be used.

Hemlock Extract and Sulphite Liquor. (*U. S. Consular Report*, July, 1910.)—The U. S. Consular Agent at New Castle, New Brunswick, reports that at a factory making hemlock-bark extract, the important discovery has been made that the residual liquor from sulphite pulp mills acts on the extract of hemlock bark, producing a larger percentage of tannin. This discovery has greatly aided the industry of producing extract of hemlock bark.

Influence of the Size of Ingots on Segregation. H. M. HOWE. (*Trans. Amer. Inst. Min. Eng.*, xl, 644.)—The larger the size of the ingot the greater the degree of segregation. The effect of increase of size on segregation is relatively slight until the thickness of the ingot is about 20 inches; with further increase of size the degree of segregation rapidly rises. The segregation of sulphur is greater than that of phosphorus, and that of phosphorus is greater than that of carbon. Marked segregation may take place even in small ingots. A small ingot, 5 in. long and fifteen-sixteenths of an inch in its widest part, of acid open-hearth steel, was quenched in water from a moderate red-heat. The outer portion of the ingot

contained 1.08 per cent. of carbon, but microphotographs of the metal around a small cavity in the upper part of the axis of the ingot showed that some of the metal had been converted into white cast-iron (about 3 per cent. of carbon) whilst the eutectic areas must have contained more than 4.3 per cent. of carbon.

Prevention of Corrosion of Iron and Steel. G. W. THOMPSON. (*Amer. Inst. Chem. Eng.*, 1910.)—Corrosion is best prevented by applying successive coatings of paint to the clean metal surface. The pigments should contain no hygroscopic nor water-soluble matter, nor substances capable (by reduction) of acting as depolarizers, and as far as possible should be non-conductors of electricity and inhibitors of corrosion. The use of linseed oil as a priming coat is condemned. The metal should be thoroughly cleansed before the application of the paint.

Aluminum Nitride. D. WOLK. (*Comptes rend.*, cli, 318.)—When aluminum powder is heated in the products of decomposition of gaseous ammonia, the nitride is formed at a temperature of 820° – 850°C . The production is very rapid at 1000° , but above 1100°C . the product crumbles and begins to dissociate. The nitride contains 33.6 per cent. of aluminum (the compound Al_2N_3 contains 34.00 per cent.), and forms a gray mass. The lower the temperature of its formation the more readily it decomposes in water. Apparently no intermediate amide is formed.

Nitrate Deposits of Southern California. F. W. GRAEFF. (*Eng. and Min. J.*, xc, 173.)—These deposits are in the Chemehuevi Valley, 33 miles south of Needles, Cal. The bed is covered with clay overlaid with gravel, except where the clay has been denuded on the hills, which are from 100 to 300 ft. high. The nitrate is mainly contained in the clay strata, the content varies from 7 to 22 per cent. sodium nitrate together with sodium chloride, sodium sulphate and calcium sulphate. The overburden is soft and blasting is unnecessary. The Colorado River supplies the water requisite for extracting the nitrate.

Progress in the Ceramic Industry. W. PUKALL (*Ber.*, xliii, 2078.)—An account is given of the development and present condition of the ceramic industry. Some highly interesting experiments on the chemistry of the silicates are described.

The Prevention of Power Monopoly. H. KNOX SMITH. (*Eng. Record*, lxii, 11.)—A well considered article on the best method for the Federal Government to control the monopoly of water-power sites before private rights accrue. Eight main points are given which the controlling authority should bear in mind when granting water-power privileges.

A Cobalt-Chromium Alloy. ELWOOD HAYNES. (*Iron Age*, lxxxvi, 9.)—The first experiments were undertaken by Mr. Haynes in 1895 towards the production of alloys of nickel with iron, chromium and other metals. In 1905 some of these were repeated with a view to utilizing the alloys of cobalt and nickel with chromium for ignition-points in gas engines. The final product was an alloy containing 75 per cent. cobalt and 25 per cent. chromium, which could be hammered into thin sheets at a bright red heat without cracking. This alloy has an elastic limit of 79,000 lbs., a tensile strength of 96,000 lbs., and an elongation of 3 per cent. By reducing the quantity of chromium and adding other metals alloys are said to have been produced which are proof against nitric acid and sufficiently malleable to be worked cold. Other combinations have produced alloys which would scratch quartz crystal. The most remarkable property of a combination of 3 parts cobalt and 1 of chromium is its resistance to corrosion.

Alcohol from Sulphite Cellulose Waste Lyes. C. G. SCHWALBE. (*Zeit. Angew. Chem.*, xxiii, 1537.)—Wallin, at Forss, neutralizes the crude acid lyes with lime. Ekström, at Skutskär, Sweden, uses the waste causticization-sludge from sulphite cellulose mills; after neutralization the lyes are cooled and aerated in towers. It is said that the neutralization-sludge if used to prepare fresh lyes contains sufficient calcium sulphide to save 40 to 45 per cent. of the sulphur required. A yeast nutrient, malt-extract, or dead yeast is added to the neutralized, cooled and aerated liquid, and fermentation is set up. After fermentation and separation of the yeast the lye is distilled. This alcohol is obtained denatured as it contains considerable proportions of methyl alcohol, aldehydes, furfural and probably acetone. The yield is about 60 litres per ton of cellulose, or 50,980 litres monthly.

Reform in Specifications for Petroleum Products. DR. ALBERT SOMMER. (*Eng. Record*, lxii, 6.)—This is an interesting and valuable paper for consumers of petroleum products, and will repay careful perusal. Dr. Sommer points out that present specifications usually cover gravity, flash-point and burning-point, cold-test and sometimes color-test, but that these tests do not determine the value of an oil in practical use and at best are only descriptive. He recommends as the basic principles for tests which will indicate the practical value of an oil (say for the automobile user or gas maker) as (1) heating the oil at a certain fixed temperature for a certain number of hours; (2) precipitating the asphalt formed in the same by means of petroleum ether or other alcohol; (3) determining the so-called coke or tar value in the oils before and after heating by means of caustic soda and benzol; (4) determining change of fluidity by a quantitative method; (5) emulsion test of oil with water at various temperatures.

Colloidal Barium Sulphate. Y. KATO. (*Mem. Coll. Sci. and Eng.*, Kyoto, ii, 187.)—To a solution of barium acetate, prepared by diluting a gram-molecular aqueous solution with six times its volume of alcohol, was added an alcoholic solution of sulphuric acid, prepared by diluting a molecular aqueous solution with twice its volume of alcohol. The milky solution and jelly-like precipitate thus obtained were evaporated to dryness, under reduced pressure, at a temperature below 40°C. Colloidal barium sulphate was thus obtained as a translucent, casein-like mass, readily soluble in water, the solution being fluorescent. The solution of the colloidal sulphate is, in general, coagulated by electrolytes; the coagulating power of different anions increases with their valency, according to Hardy's Law, and dissociating electrolytes have a higher coagulating power. Cations of high valency interfere with the coagulating action of anions.

Testing the Hardness of Metals. A. F. SHORE. (*Iron Age*, lxxxvi, 9.)—This is a highly interesting and valuable paper for automobile engineers and those interested in the hardness of metals. It is pointed out that there are many different kinds of hardness; viz., tensile hardness, cutting hardness, abrasive hardness, elastic hardness, static hardness, and shock hardness. According to Mr. Shore's view there is but one really important hardness, which may be defined as rigidity and resistance to penetration or deformation. Possibly this might be called tensile hardness.

Measuring Aeroplane Altitudes. AUGUSTUS POST. (*Amer. Mach.*, xxxiii, 35.)—To accurately determine the altitude reached when W. R. Brookins broke the world's record for height with an aeroplane at Atlantic City, a base line $2\frac{1}{2}$ miles long was chosen. An engineer's transit was placed at each end of this base line with its telescope clamped in the vertical plane passing through the line, and by sighting upon the aeroplane as it passed above, the vertical angles at each end of this line were determined. Knowing the base and two angles of this triangle, the altitude was easily and accurately calculated. A recording barometer was used as a check. Full details are given in this interesting article. Also a description of a simple, but remarkably accurate method used by the Wrights for ascertaining altitude. Such measurements will be of the utmost importance in finding the range of an aeroplane in war time.

Scandium. SIR W. CROOKES. (*Phil. Trans. Roy. Soc.*, A209, 15.)—Scandium has been found to the extent of more than 1 per cent. in the mineral Wiikite from Finland, and in small amounts in many other minerals. By a systematic series of fractionations it is possible to separate scandium from most associated elements; ytterbium is the most difficult to separate because its nitrate is decomposed almost as readily as scandium nitrate. In view of the

atomic weight relationships, and of the frequency with which these elements occur together in nature, it is suggested that yttrium and scandium are degradation products of ytterbium. Scandium can be separated from yttrium and ytterbium by precipitation as meta-nitrobenzoate.

Paper from Megasse. CARMODY. (*Bull. Imp. Inst.*, viii, 151.)—Megasse is more suitable for paper making when it is mixed with other fibrous materials such as banana leaves and stems, maize residues, bamboo, sunflower or native grasses, etc. The best results are from a mixture of megasse, bamboo and Para grass. It is estimated that there are 50,000 tons of megasse available per annum in Trinidad. This would yield 40,000 tons of pulp worth at least one million dollars, or 30,000 tons of better quality pulp worth \$1,800,000. If the megasse were mixed with bamboo and Para grass the pulp would be worth \$2,250,000.

Vanadium in Cast-Iron. GEO. L. NORRIS. (*Iron Age*, lxxxvi, 5.)—Vanadium entered into practical metallurgy about 1903, when rich deposits of it were discovered in the Andes of Peru. Vanadium exerts a very powerful influence on steel. One or two tenths of 1 per cent. raise the elastic limit of mild carbon steel about 50 per cent. or more, without impairing the ductility, and vanadium steels have a very high dynamic strength. Vanadium cleanses the cast-iron from oxides and nitrides, eliminates porosity and produces sound castings. In chilled cast-iron vanadium produces a deeper, stronger chill, and one less liable to spall or flake. It greatly diminishes the wear on cast-iron cylinders. In malleable cast-iron the tensile strength is improved about 12 per cent.

Action of CO and H, or CO₂ and H on Iron Oxides. A. GAUTIER AND P. CLAUSMAN. (*Comptes rendus*, cli, 355.)—A mixture of 3 volumes of CO and 1 vol. H was passed at 300°C. over ferroso-ferric oxide. The product contained about 7 per cent. carbon, the remaining 93 per cent. being about one-half ferrous oxide and one-half iron carbide. When steam was passed over this at 400°C., a gas was obtained containing 96 per cent. H and 4 per cent. CH₄. If two volumes CO₂ and 1 volume H were passed over iron at 1250°C., the issuing gas consisted of 23 per cent. CO, 76 per cent. H and 0.15 per cent. CH₄. A mixture of equal volumes of CO and H, saturated with H₂O vapor was passed over Fe₂O₃ at 250°–300°C. and the resulting gas was heated to 500° or 600°C. Besides permanent gases a small proportion of a substance, condensible to a jelly like solid, like vaseline, was obtained. These experiments may have a bearing on the geological formation of hydrocarbon gases and petroleum.



The JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA

DEVOTED TO SCIENCE AND THE MECHANIC ARTS

VOL. CLXX

DECEMBER, 1910

No. 6

THE GENERATION OF POWER.

BY

D. S. JACOBUS, E.D.,

Advisory Engineer, The Babcock & Wilcox Co., New York.

(Address delivered before the Mechanical and Engineering Section, Thursday, November 10, 1910.)

No art has developed within the last few years at a more rapid pace than that of the generation of power. This development has been in the line both of an enormous increase in the amount of power produced and in the economy with which it is generated. With this have come developments in the electrical field and so closely are the two related that the unit of measurement of efficiency of our power plants is usually expressed electrically, that is, in the cost required to generate one k. w. of electrical energy per hour, or the amount of fuel, or its equivalent heat value, required to generate a k. w. hour.

The great advance in artificial illumination brought about by the electric light, the establishment and extension of trolley lines for city and interurban service and the distribution of power to both small and large consumers, have heavily taxed the resources of our central power plants, which have been continually increased in capacity to meet the demands. So rapid has been the advance that what was the best practice but a few years ago is in most cases not the best practice of to-day, and it is

[NOTE.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

no rare occurrence to see equipments which were up-to-date less than ten years ago replaced by something better. The development of the steam turbine has had much to do with this—a development which has proceeded so rapidly that it must be regarded as one of the marvels of engineering.

Steam is to-day the ruling power. Hand in hand with steam come the gas-engine and hydraulic-power developments. Each has its own particular field and any individual case must be considered by itself before it is possible to say which form of power will be the most economical. Of these three methods of generating power the hydraulic surely has the advantage as far as the conservation of our natural resources is concerned, but history has shown that the development of most water powers is simply a preliminary step to the installation of an auxiliary steam plant to insure continuity of service, and in many cases the power demands become such that the steam plant is eventually the more important of the two. What follows will bear more especially on the production of power by steam.

We often hear the cry that we are a wasteful people and that we should save our coal deposits and make more use of such natural powers as the wind and the waves. These methods of producing power, especially in the case of the wind, have filled particular needs, but as a means of generating the large quantities of power now used for industrial purposes they would be completely inadequate. For example, let us consider the power generated by a single steam turbine of 20,000 k. w. capacity. To produce this power with windmills each having wheels 25 feet in diameter and with a wind velocity of 20 miles per hour we would need over 6000 windmills, and if the mills were placed 50 feet apart they would form a line about 60 miles long.

Again, let us compare the power obtained from the steam turbine with that available from a wave motor. If we should construct a wave motor which would convert half of the total energy contained in the waves into electrical current and which would be operated by a continuous series of waves 200 feet long and 4 feet high, it would have to extend along the coast for a distance of about a mile and a third to give as much power as the single steam turbine. The cumbersomeness and cost of constructing such a wave motor would render it impracticable,

whereas for certain uses where smaller amounts of power are needed a wave motor might be developed to serve the purpose.

Let us consider animal power. A horse develops, say, three-quarters of a steam-engine h. p. under favorable conditions, which means that about 35,000 horses would be required to do the work of the single 20,000 k. w. steam turbine.

The consideration of the subject from a theoretical standpoint is most interesting. The steam-engine is handicapped in its efficiency as compared with the gas-engine by the lower initial temperature of the working fluid in the cylinder, whereas the gas-engine is handicapped as compared with the steam-engine by not being able to make use of a low temperature at the end of the cycle. In a steam-engine a great part of the work is done by the steam at a pressure below the atmosphere, every degree that the condensing water is lowered being available for increasing the work and representing the lower limit of temperature. The steam turbine is especially adaptable for utilizing the low temperature at the end of the cycle. In a gas-engine the lower limit of temperature is that of the hot gases at the end of expansion, a temperature usually higher than the initial temperature of the working fluid in a steam-engine.

The question is often asked why a good arrangement could not be obtained by combining a low-pressure steam turbine and a gas-engine so as to secure the benefits of the high initial temperature in the gas-engine and the low final temperature in the steam-engine. On working out an actual example, however, it will be found that the work of the steam turbine would be comparatively small, amounting to less than 10 per cent. of that of the gas-engine, so that the installation of the steam turbine would not as a rule increase the capacity or efficiency enough to warrant the additional expense and complication of the plant.

Many so-called new cycles for the production of power have been brought out from time to time. In most cases these cycles serve as an illustration of the old adage, that a little knowledge is a dangerous thing. The inventors often work out pages of thermodynamic formulæ to uphold their views. In other cases the problem is dealt with in broad generalities, heat units being handled as if they were packages that could be moved at will from shelf to shelf and so made to pass from one part of the

apparatus to the other without loss, no consideration being given to the amount of surface required to effect the transmission or to the radiation losses. In some cases heat is assumed to be transferred from one part of the cycle to the other, no proof being offered that the interchange will be possible, that is, from a hotter to a colder medium. Still other inventors actually build machines only to find that this is the most expensive way of becoming convinced that they are mistaken. I have had to examine many such schemes and in most cases it could be readily shown that the cycle was at variance with the well-known laws. Cycles that do not conflict with the laws can usually be shown to be impracticable when the sizes of the parts necessary for an actual machine are computed and the radiation losses allowed for. If we could but find a way of disposing of heat at a temperature lower than that of the surrounding objects, we could utilize all of the heat of the ocean or the atmosphere to develop power. Many of the schemes advanced in the so-called new cycles are equivalent to this and the inventors have wasted their energies in striving for the impossible.

Much depends on the load curve of a power plant in obtaining economy. If a continuous uniform load could be carried many of the vexing problems which confront the power plant engineer would be eliminated. It is difficult to carry economically enough reserve capacity to meet the daily peaks in the load. Then again, there are exceptional peaks which occur only at rare intervals, so that a considerable percentage of the available power may be developed only for a few hours every month, or for that matter, for a few hours every year. Modern practice leads more and more to developing higher ratings from boilers during such intervals, and a boiler should be used which, under proper operating conditions, may be driven to a capacity that is limited only by the amount of coal which can be burned in the furnace. Again, it is desirable to use boilers that may be cut into the line quickly either from banked fires or starting from a cold state.

The practice in this respect is exemplified by considering the installations of the Commonwealth Edison Company at Chicago, where the first 5000 k. w. turbines erected in this country were installed. This was in 1903, and eight boilers each having about 5000 square feet of heating surface were supplied for

running a turbine. The maximum rating for these turbines was 7500 k. w. Later on 12,000 k. w. maximum rating turbines were installed, each with eight boilers of the same size as provided for the 5000 k. w. machines. Still later machines of 14,000 k. w. maximum were run with the same size and number of boilers as the original machines of 7500 k. w. maximum.

The steam pressure in power plants of this country is usually about 185 pounds to 200 pounds per square inch and about 150° of superheat is carried. The economy of superheat in this work is well established and represents the best practice.

The steam turbine is becoming more and more the standard for large power-plant work, both on account of its fuel economy and the low cost of attendance. The most economical fuel consumption under operating conditions that has so far been published was obtained in a test with piston engines where a k. w. hour was turned out of the station for each 25,000 B.t.u. contained in the fuel. The station referred to is the Redondo plant of the Pacific Light & Power Company of California, and the results of the test, at which I was fortunate enough to be present, were given by the designer of the plant in a paper published in the *Transactions of the American Society of Mechanical Engineers* for 1908. The fuel was California crude oil. The load curve had two high peaks and the entire plant was shut down during a lay-over period of four and a half hours per day. The 25,000 B.t.u. represent the heat of combustion of the oil used per k. w. hour net electrical output for the entire fifteen-day period during which the test was run. It is a fact worthy of note that this result approaches that to be expected for the plant economy of large gas-engines for the class of service considered where the power is variable and reductions must necessarily be made for all the auxiliaries, etc.

While no results for plant economy as good as the above have been published for steam turbines, it is only fair to say that the figures for steam consumption for turbines show that better than this economy can be obtained under uniform load conditions. When it comes to plant economy so much depends on the load conditions that it is hard to compare one plant directly with another.

We have in this country many large power plants: In New York we have the Edison Waterside Stations and the Interbor-

ough Station; in Boston the Boston Edison Company's Station, and in Chicago the Commonwealth Edison Company's Stations, two of which, built near each other, at Fisk and at Quarry Streets, have an aggregate maximum capacity of over 200,000 k. w. It is noteworthy that the first 5000 k. w. turbines installed in this country, which have already been referred to, were placed in the Fisk Street Station about seven years ago. The rapid development in the art is exemplified by the fact that these turbines are now replaced by others, although at the time they were installed they represented the latest advance in power-plant practice.

The growth in the consumption of power has been so enormous that the question is often asked, Where will it stop? What is a luxury to-day becomes a necessity to-morrow. Where our grandfathers used the tallow dip and oil lamps we must now have a flood of light rivalling that of the sun itself. Our streets are illuminated in a way that our forefathers would have considered impossible and no one would wish to go back to the darkness that would tempt the highwayman and render travel difficult. Ventilating fans are now regarded as a necessity and electrical current is used for a number of household purposes. We could not indeed go back to the old days without giving up many comforts. But where will this great increase in the demands on nature's coal pile land us? This we will have to leave to others to answer. Let us stop for a moment, however, and compare what we are doing with that great silent source of heat and power—sunshine. The sun shining on the world for a single minute imparts as much heat as that contained in all the coal and oil produced in our country in a year, and when we make this comparison we cannot help but appreciate the littleness of our endeavors and have confidence in the great recuperating powers of nature.

After the presentation of the paper, lantern slides were exhibited showing the equipment of several modern power plants and illustrating marine boiler practice. The Fisk and Quarry Street plants of the Commonwealth Edison Company at Chicago were fully illustrated as well as the plant of the Pacific Light & Power Company at Redondo, California.

The type of boiler best suited for power plant work was then discussed by Dr. Jacobus, his remarks on the subject being as follows:

The boiler that is best suited for power plant work, in addition to being

economical, should be capable of being driven with clean feed water to a capacity limited only by the amount of coal that can be burned in the furnace. It should also be of a type that can be gotten under steam and cut into the line quickly, either from banked fires or from a cold state. The thermal storage factor should not be increased by adding to the water capacity to a degree which would sacrifice the ability to get up steam quickly, as under the conditions met in ordinary power plant work an increase in the thermal storage capacity is of less advantage than the ability to get a reserve boiler in on the line in the shortest possible time. The best boilers to use are those that will respond quickly, and by having a number of the boilers in the plant under steam and others in reserve the steam pressure may be maintained practically constant. To make thermal storage a material factor the steam pressure must fall, say, 25 pounds or so, and after the pressure falls the thermal storage will act against the recovery of the pressure, hence during the period of recovery the rate of combustion of the fuel and the heat imparted to the boilers must be greater than with the boilers having a less thermal capacity.

The great problem in power plant engineering is to economically carry enough reserve capacity to meet the daily peaks of the load. Then again there are exceptional peaks which only occur at rare intervals, so that a considerable percentage of the available power may be developed only for a few hours every month, or for that matter, for a few hours every year. For this class of work the Babcock & Wilcox boiler has proved to be pre-eminently successful, so much so that it has been one of the important factors in power plant development. It is good modern practice to drive these boilers daily at double the nominal rating during peak load periods. This does not mean that the boiler is driven to an overload in the sense that it is under a strained condition of running, as the rating of 10 sq. ft. per boiler horsepower is simply an arbitrary one. The speaker believed that eventually boilers would be operated harder than this during peak load periods, and that additional plant economy would be secured thereby.

In marine boiler practice Babcock & Wilcox boilers have been driven to give an evaporation about four times as much as that based on the nominal rating of 10 sq. ft. per boiler horsepower, hence there is a considerable margin for increasing the rate at which boilers can be driven in power plant work. The economy at this high rate of driving does not fall off as much as one might expect, as most careful tests show that the efficiency of a Babcock & Wilcox marine boiler for such an overload is over 60 per cent. In power plant practice it would pay to run the boilers at a high rating during peak load periods even though the efficiency should fall lower than this, because a great saving is effected in cutting down the fuel required to keep banked fires in the boilers held in reserve and to bring up cold boilers to be run during the peak load intervals. With chain grate stokers, such as were described in connection with the Fisk and the Quarry Street Plants, the best efficiency is reached at slightly over rating and remains constant to nearly double rating. The reason for this is that as the rate of combustion of the coal becomes greater the furnace efficiency increases to a sufficient extent to offset the loss of heat absorptive efficiency of the boiler. It is therefore apparent that under these conditions the best commercial economy is obtained

by following the practice described and operating the boilers at double the nominal rating.

Some questions were asked by a member in regard to tube failures in Babcock & Wilcox boilers. He said he had been informed that after the marine boilers were run in a trial for maximum speed the lower tubes were sprung and distorted and that the circulation was defective under certain conditions, so much so as to cause accidents through tube failures. He further said that in his opinion a greater amount of boiler heating surface than the present practice calls for should be provided for power plant work, rather than a smaller amount.

In replying Dr. Jacobus said that one of the requirements for boilers for the U. S. Navy, where many of the marine boilers are installed, is that the boilers shall show no distress after being forced during a trial of maximum speed and subjected to an endurance run, and that as the acceptance of the boilers depended on conforming with this requirement it would be evident to anyone that there were no grounds for the statement which had been made. Furthermore, he said that he could certify to the fact from personal observation that the tubes were straight after such endurance runs. When it came to circulation he could further say that he had made tests which indicated that there was a large margin of safety in this respect. He had made tests on a boiler where the tubes were 20 ft. long instead of 18 ft., as adopted in power plant practice. In these tests the lowermost tubes were heated their full length by hand firing bituminous coal on a grate which extended under the entire boiler and the boiler was run for weeks at over two-and-a-half times the ordinary rating, with no distress to the tubes. He further said that in these tests the steam pressure on the boiler had been varied by special means so that it was made to fall suddenly and was afterwards made to recover in as short a time as possible, thus indicating that any variation in the flow of the steam from the boiler would not cause trouble. In some of the tests the boiler was driven to over three times its rating. Ordinarily less than one-half the length of the lowermost tubes are subjected to the full heat, hence, as the tubes in the experimental boiler were 20 ft. long instead of 18 ft., it would follow that the heat imparted to the lowermost tubes was two or three times that which ordinarily exists during peak load periods in power plant work, showing that there is a large margin of safety. He further said that the tubes remained in good shape under severe service conditions at the Fisk and Quarry Street Stations, where the boilers are run continually when in service at almost double their rated power, one boiler after another being cut in to carry the load. At the time he was at Quarry Street two insurance inspectors had gone over all of the boilers and had ordered out only one tube, and even this single tube was not in a very bad shape. In reply to the statement that more surface should be provided per horsepower than that ordinarily adopted in power plant work, Dr. Jacobus reiterated that, in his opinion, for this class of service where there are peak load periods the amount of heating surface per kilowatt output will be decreased instead of increased as the art advances.

With perfectly clean water there is little danger of tube difficulties, whereas if the least trace of oil finds its way into a boiler it may cause

trouble, especially if salt, due to leakage at the condenser or from some other source, is present at the same time. A loose scale may also cause trouble. The action of such foreign substances inside the tubes is to cause blisters, which ordinarily will bulge out and possibly open slightly. If it so happens that there is a flaw in the tube at the point where the blister is formed, the tube may open up, and if the opening is large enough an accident may result if anyone is caught in a confined space and cannot get away from the boiler. A boiler under steam is a magazine of energy and just as long as boilers are used there may be accidents. Disastrous explosions, however, such as we often hear of in connection with shell boilers, are impossible with Babcock & Wilcox boilers, and the Company takes particular pride in the fact that the Babcock & Wilcox boiler is universally conceded to be the highest type of the "so-called" safety boiler.

A number of other questions were asked and were replied to as follows:

Engineers differ as to the best size of boiler for power plant work; personally, he believed in units of about 500 or 600 h.p., as with larger units, say, of 1000 h.p., cutting out a boiler for cleaning or repairs would diminish the capacity to a greater extent proportionally than by cutting out one of the smaller units.

The superheat cannot become excessive so as to give a temperature in the neighborhood of 1000° F. with a Babcock & Wilcox superheater placed within the boiler setting, as one of the audience had heard that it might. Actual measurements show that the superheat is comparatively uniform instead of varying through any wide ranges of the sort. The only time that there could be an excessive superheat would be when the power is suddenly thrown off the boilers when the latter are working at their maximum load, which might occur if there is a short circuit in the electrical apparatus. In this case it might seem that with only a very small amount of steam flowing through the superheaters, or possibly with no steam at all, and the fires burning up to the maximum, the superheaters would be greatly overheated. Such is not the case, however, as each superheater is fitted with a safety-valve which blows at a few pounds less than the main safety-valves of the boiler, and in such an emergency the steam will circulate through the superheaters and in this way eliminate any excessive superheat.

Measurements of superheat taken on a single boiler may vary to a considerable extent on account of irregularity in the operating conditions; for example, should the water tender allow the water to get low in a boiler and then feed the boiler up quickly with cold water, the steam generated by the boiler during the feeding-up period would be considerably less than normal. During this time less steam would be flowing through the superheater in proportion to the heat outside of it than under normal operating conditions and the superheat would increase. Variations in the furnace conditions also cause the superheat to vary. Where the steam from a number of boilers is mingled before passing it to a steam-engine or turbine the irregularities are averaged and the superheat will be comparatively uniform.

In regard to loss of economy due to excess air: it is a fact that much could be gained in many plants by reducing the amount of such excess. It should be remembered, however, that in making analyses of flue gases the

carbon monoxide should be determined accurately as well as the carbon dioxide. In many cases a small amount of carbon monoxide may escape notice in the analysis, whereas it may have a considerable effect in reducing the economy. In analyzing for carbon monoxide two absorption pipettes should be used, the second pipette being employed to remove any of the gas not absorbed by the first. The solution should be fresh and active. In obtaining the highest efficiency it is often more difficult to eliminate the carbon monoxide than to obtain a high carbon dioxide reading.

The class of attendance in boiler room work was next discussed. The managers of power plants are now appreciating the fact that it pays to obtain the services of high-class men in the boiler room, and a much better class of boiler room engineers are employed than formerly. More can be lost or gained in the boiler room than in any other part of a power plant, and it is false economy to employ other than a capable engineer, as such a man can save his company many times the cost of his services.

The advisability of casing-in power plant boilers with a metal covering to eliminate leaks through the setting was also discussed. This method of eliminating leakage is growing in favor, the advantage gained over a leaky setting justifying the additional cost.

The question was asked how much scale should be allowed to accumulate in a boiler before cleaning. The reply to this was that a feed water which would form any material amount of scale should be given a preliminary treatment that would prevent any scale forming in the boiler. It is dangerous to attempt to loosen the scale in a boiler operating under working conditions, as a piece of loose scale or a little pile of the loose scale may prevent the water from acting on the inner surfaces of the tubes and a blister may result. When using a water which forms scale very slowly it would not seem advisable to run with much over a $\frac{1}{32}$ in. scale in the tubes; in any event, the scale should not be permitted to accumulate to such an extent that it cannot be readily removed by a turbine cleaner. In case a boiler has been allowed to accumulate a hard scale it is often well to soften the scale before attempting to get it out with the cleaner, but in softening the scale the boiler should be cut off the line and run with a slow fire, any steam generated being allowed to escape through the safety valves.

Aeroplane Construction. W. H. MILLER. (*Amer. Mach.*, xxxiii, 29.)—A most interesting and instructive article that will repay careful perusal. It might be summarized thus: The framework is made of many different materials; while bamboo is light and strong, its natural joints interfere too much with construction, so light bicycle steel, hickory, and ash are substituted. Many constructors consider wood preferable to steel for parts under compression as less liable to buckle. Steel wire, tautened by turnbuckles, or U bolts, is used for tension members. Rubberized linen is used for wing surfaces. Wings are sometimes made to fold. The location and control of the stability planes varies, in the endeavor to use as few levers as possible.

RECENT ADVANCES IN THE CONSTRUCTION OF FIRE- AND BURGLAR-PROOF SAFES.

(Read at Stated Meeting of the Institute, held Wednesday, October 19, 1910.)

BY

MR. E. E. WATSON,

Factory Supervisor, Herring-Hall-Marvin Safe Company, Hamilton, Ohio.

[In this article is presented an interesting account of the progress made in lock-making and safe-building during the past century.]

IN order to place before you the recent advances in the construction of fire- and burglar-proof safes, it is necessary to cover a brief history of the industry from its actual beginning in the early part of the Nineteenth Century down to the present time.

Practically speaking, the more recent advances have had to do principally with refinements in mechanical processes, the development of factory organization and the perfection of elements of design that were conceived long before the means were at hand for their proper realization.

The development of any industry is in a large measure dependent upon the activity in other related industries, and the progress in the one must mean a general forward movement on the part of all.

The development of the art of building safes for the protection of valuables is interwoven so closely with that of the art of lock building that the two subjects necessarily must be treated together.

It is a fact that is apparent to anyone who gives consideration to the subject, that a safe, however secure from the stand-point of construction, would be useless without an opening giving free access to its interior, and that opening guarded by a lock at least as secure in point of design and construction as the safe itself.

The conclusion must be drawn from this that safe building, in point of relative security, could only keep pace with the development and with the design and construction of locks. The history, therefore, of the development of the safe building art is in reality, first, the history of the development of locks.

Locks, as we know them to-day, and as they have been known ever since they were first used, consist primarily of a bolt and a key for operating the bolt, and some means interposed between the key and the bolt to render the operation of the bolt either more or less difficult or impossible without the use of the proper key.

The means employed for housing the working mechanism of the lock, and for applying it to the protected structure, are of little importance in this consideration. All of the different locks possess these features. They may be divided into several general classes.

First, not only in point of simplicity, but naturally also in point of historical origin, is the latch lock, in which there is a bolt pivoted on a fixed point and raised by some sort of a key.

Locks were later rendered more secure by the introduction of the warded type in which the introduction of the key into the hole provided for it was rendered more or less difficult by means of interposed wards, making it, to a degree at least, impossible to introduce the wrong key.

The warded type of lock was succeeded by the present day lever tumbler type, in which tumblers are interposed between the key and the bolt, making it necessary for the key to lift the different tumblers before the bolt can be withdrawn. This type of lock is considered secure in proportion to the number of tumblers used and the means provided for varying the relative amount of lift.

The bolt of this type of lock has fitted to it a member that passes into slots in the lever tumblers in the operation of its withdrawal, and the province of the key is to line up these slots in the lever tumblers so that they register with the fixed member on the bolt.

A later development of the tumbler type of lock is that known as the cylinder pin-tumbler lock. In this type of lock the obstruction consists of divided pins preventing the turning of the plug until these pins have been raised to a point where the division line between the different sets of pins coincides with the outer surface of the plug, and the inner surface of the cylinder, in which it rotates. When these points have been so lined up by the introduction of the proper key the cylinder may be rotated and the bolt withdrawn.

The inconvenience resulting from the use of the ordinary type of key lock, by reason of the fact that keys could be wrongfully

duplicated, or they might in various ways come into the possession of persons not entitled to them, gave the necessary impetus to inventive genius, and the modern dial or combination lock was the result.

Coincident with the development of the dial lock is that of the changeable type of key lock, in which the arrangement of the tumblers or obstacles may be almost indefinitely varied. It practically, after being set up to a new key, becomes an entirely new lock and cannot be operated by any other key than that to which it is set up.

The development of the changeable-key type of lock is of great importance for the reason that a limited amount of security is frequently needed of a kind that cannot be afforded by the ordinary type of lock. This security is frequently furnished by combination or dial locks that are much more expensive.

The changeable key locks, until recently, have been of a design and construction that were very apt to get out of order and cause considerable inconvenience to the user.

Many efforts have been made to produce a simple lock of the changeable-key type, all of them depending upon the introduction of a double tumbler between the key and the bolt. The changeable-key lock that is being manufactured by the Herring-Hall-Marvin Safe Co. is the only one in which the obstacle that is interposed consists of a single member. The tumbler of this lock departs from the lever tumbler type previously employed in that it has no fixed pivot but can be properly called a balanced tumbler.

Its greatest merit is its simplicity and its substantial construction. In all other types of changeable-key locks the means provided for changing the combination are delicate, and in the ordinary operation of the lock the wear on these delicate parts is constant. In this lock the means provided for changing the combination are not in the least delicate, and the ordinary operation of the lock in opening and closing after it has been set up to a key causes absolutely no wear on the combination part of the tumbler, making the lock just as substantial, and as little liable to get out of order as the simple lever tumbler type of lock.

It is generally conceded by those who are interested in the manufacture and sale of locks that the changeable-key type of lock has been greatly limited in its use heretofore by reason of its delicacy, and its propensity for getting out of order.

As an evidence of the simplicity of the Herring-Hall-Marvin Safe Co. lock, it is necessary only to call attention to the fact that in this lock, which admits of over 59,000 different changes, there are but 14 parts, while in the highest type of changeable-key lock previously invented, which afforded but about 8000 changes, there were over 40 parts.

Its application, while not exactly universal, is broad enough to enable it almost entirely to supplant the other types of key locks.

In the case of apartment houses, where tenants are constantly changing, the ordinary type of lock affords absolutely no security, for the reason that keys may be duplicated. With the changeable-key type of lock it requires but an instant of time to set up the lock to a new key and thereby render all previous keys inoperative.

The combination lock, as it is known to-day to distinguish it from the key lock, became a necessity when it had been demonstrated that practically all key locks could be picked. This fact was developed in the historic lock controversy of 1851, in England, when Mr. Hobbs succeeded in picking all of the best makes of locks.

A few years later, to be exact in 1856, Mr. Linus Yale, Jr., succeeded in picking several of the Hobbs locks. It then became generally conceded that no difference what the obstacles were that were interposed between the key and the bolt so long as an opening was left for the insertion of the key, this same opening provided means for the insertion of picks to raise the tumblers. Mr. Yale then turned his attention to the designing of a lock that could be operated in some manner other than by the insertion of a key, and the early type of combination lock was the result.

The combination lock, being in such general use to-day, needs no lengthy description. It consists of the tumblers, the bolt, a lever member interposed between the tumblers and the bolt, and a spindle or arbor, having on its inner end a driving tumbler and on its outer end a dial. The lever member is usually characterized as a fence, and is, from the stand-point of security, a very important part of the combination lock.

The first locks were fitted with a gravity fence, and it was later found that the disc tumblers could be rotated so as to bring their notches in line with the fence even when the combination

was unknown. The fence rested upon the periphery of the discs and could with patience and a delicate sense of touch, be felt into the notches one at a time until all of the discs were lined up, when the bolt could be retracted by simply turning the dial. This defect was a serious one. It was finally overcome by Mr. Emory Stockwell of the Yale Bank Lock Department, by the invention, in 1884, of the balanced fence. This fence was so supported that it brought no weight to bear upon the periphery of the tumblers. It was fitted with a friction bearing and could be moved out of its neutral balanced position only when the tumblers or discs had all been lined up in registry with it.

This improvement rendered the combination lock absolutely unpickable. It, however, remained for the ingenuity of the burglar to devise ways and means for defeating even this supposedly perfect lock. It was evolved out of the fertile brain of some enemy to organized society, that a mental key always existed and could be secured by torture—the combination numbers were always known by some one. There began, in the year 1874, a series of bank robberies all over the United States, the most important of which were carried to a successful termination by reason of this one weakness of the combination lock.

It immediately became evident that a lock with absolutely no communication with the outside of the protected structure was necessary and essential to security, and the invention of the time lock followed. This was and still is, to a large extent, used in connection with the combination lock. Its use prevents the operation of the combination lock until such time as the time lock has run down and, by so doing, withdrawn its obstruction to the operation of the combination locks themselves, or the means provided for opening.

Meanwhile, in an entirely different field, inventive genius had been equally active by the invention of liquid high explosives, the fluidity of which could be increased by the addition of liquefied ether, so that it could be made to flow into the space surrounding the lock spindles or into the joint between the door and the frame. The burglar, without first securing any proprietary rights in the invention, adopted this method and the battle of wits began over again, with the result that the lock makers finally evolved a motor device working in conjunction with a time lock, which made it unnecessary to connect the outside of the door with the

inside by means of spindles. The motor after being set would throw the bolts, when the door was seated into the jambs, and would instantly retract them when tripped by the running down of the time lock.

The motor device has not been universally adopted for several reasons, mainly because spindles can be, and are, made so that they cannot be driven in or pulled out, and they can be, and are, made drill-proof. They are ground into the doors so closely that no liquid can be forced around them.

In concluding that part of this paper which relates to locks, I desire to call attention to the fact that while practically all types of key locks can be picked, it does not follow that the key lock should be discarded, for the reason that the measure of security afforded by the lock need not be greater than that afforded by the protected structure itself. Manifestly a light wooden door affords very little security, yet millions of them are fitted with locks. Some with the common warded type, others with the lever and pin-tumbler types—all at least affording a measure of security equal to that of the protected structure itself.

That these locks can be picked is no argument against their use because entrance could be had in nearly all cases in an easier way. The inherent defect in all key locks, other than the changeable key type, lies in the facility with which keys may be wrongfully duplicated and used, rendering such locks of no security whatever.

The fire-proof safe which will protect its contents from destruction and bring them safely through such fires as that following the San Francisco earthquake, the Baltimore fire and the Parker Building fire, is of very modern origin.

No historical evidence exists of the use of safes for protection against fire earlier than about the year 1820, at which time a portable fire-proof safe was constructed in France. This safe consisted of an outer and an inner metal box with a space between filled with some form of non-conductor. No information is obtainable regarding the details of construction or the materials used. Previous to this the only form of fire protection afforded consisted in vaults built of masonry, which, owing to their cost, were limited in use.

In the year 1826 a fire-proof safe was invented by J. Delano. This safe was made of oaken planks three or four inches in thick-

ness, which were saturated with salt brine to render them to some degree fire-proof, and were covered on the outside with bands of iron held in place by wrought iron nails. This safe afforded only a moderate amount of fire protection. Many of them were destroyed in the great fire in New York in 1845. A safe of this type is now in the possession of the Herring-Hall-Marvin Safe Co. at its Hamilton factory.

Some time between the years 1829 and 1832 Jas. Connor, of New York City, constructed an iron box with a filling between the walls composed of plaster of Paris. He used this safe in his own office but made no attempt to patent or manufacture it. In 1834 William Marr, of England, patented a safe, the peculiar feature of which consisted of sheets of mica pasted on paper, the space between the mica sheets being filled with burnt clay and powdered charcoal mixed.

In 1838, Chubb, of London, produced a safe in which a series of iron plates were used with intermediate spaces packed with wood ashes.

Coincident with these, various other freak safes were patented and placed upon the market, but none of them seem to have left any impress of their individuality on the development of the safe industry.

The first real safe patented, manufactured and put upon the market as a commodity, was introduced by Daniel Fitzgerald, of New York City, in 1834. In this safe the fire-proof composition consisted of plaster of Paris, which was first baked and then reduced to a powder, after which it was mixed with water and mica to the consistency of paste and was poured between the outer and inner walls. This filling was a good fire resistant but its chemical action upon the iron plates composing the walls of the safe was such that it weakened the construction and rendered the safe entirely worthless in a short space of time.

Mr. Fitzgerald early associated himself with Azor Marvin, who founded the Marvin Safe Co. and was long considered one of the heads of the safe industry. This Fitzgerald safe was known as the "Salamander" safe, to distinguish it from the wood-lined chest built by Delano.

In 1843 Tann Bros. invented and patented a safe which depended for its fire-proofness upon a filling consisting of ground alum mixed with powdered gypsum. These elements were thor-

oughly mixed and melted together after which the mixture was pulverized and converted into a coarse powder and used in this form for the filling of the safe. The mixture when subjected to extreme heat would give off water. This safe was known as the Marvin Alum and Plaster Patent, and was exploited for many years.

During this time numerous other dry filled safes were invented and placed upon the market. Various kinds of heat-resisting elements were used in the filler, but the safes were not a success on account of the fact that in some instances the steel walls of the safe were corroded by the filler, and in other instances the heat-resisting qualities of the material used was low and many of these safes,—in fact the majority of them,—failed to preserve their contents when subjected to the test of great fires.

The industry was not placed upon a solid and substantial basis until after the modern concrete filling came into use. In 1865, when Jos. L. Hall, of Cincinnati, Ohio, the then President of the Hall's Safe & Lock Co., patented what was known as Hall's Matchless Concrete Filler, a safe was made that would withstand severe fire tests and would actually improve with age. This filler was composed of cements mixed with certain liquids and contained a large proportion of steam-producing elements in solid form. In addition to its non-combustible and non-conductive qualities, it has the other important advantage of materially strengthening the entire structure. It also improves with age instead of disintegrating in the manner of all other fillers that had previously been used.

The claim is made that when heat is applied to a mixture such as this, the liquid element that is contained within it, not in a liquid form, however, but in what has been characterized as water of crystallization, is upon the application of this heat converted into steam, thereby changing the heat into work and rendering it latent.

The most successful dry fillings previously used depended for their heat-resisting qualities upon this same principle, but were a failure on account of their destructive action on the steel walls of the safes, and for the further reason that they did not add any strength to the structure.

In the event of a fire a safe is apt to be subjected to a fall, sometimes from the upper floor of a building to the basement.

Its construction must be such that it will withstand this fall without exposing its interior to the destructive action of the flames. In the case of a dry-filled safe the exterior shell of metal is apt to be punctured and the dry filling sifted out, leaving some part of the safe entirely unprotected.

The concrete filling above mentioned strengthens the entire structure and by the test of great fires has proven that this added strength is one of the greatest points in its favor. The concrete filling invented by Jos. L. Hall has been improved upon and is now used exclusively by the Herring-Hall-Marvin Safe Co. in the filling of its entire line of fire-proof safes.

During the development of the industry much thought was expended upon the construction of the framework and jambs of the safe itself. A good grade of cast-iron is used in the jambs of the door and the body of the safe. This is used for the reason that cast-iron will withstand greater heat without warping than bars or plates of steel or iron. The framework of the outer box is made of angles securely welded at the corners. These angles add strength to the jamb casting and prevent its breakage in case of a fall. The outer door-plate performs the same function for the casting which serves as the jambs of the door. Particular attention is directed to this combination of metals.

The cast-iron, which will not warp under great heat, but which is apt to break as the result of a fall.

The steel angle-frames and the door-plate which add the necessary strength to the castings so that they will be able to withstand the shock of a fall.

The fire-proof safe made fifty years ago, and filled with the concrete filling, was a creditable article considering the advances made in related industries. It was not fitted, however, with an angle-hoop and the outer body of the safe was necessarily much weaker than in the safes made to-day. The fit of the doors was less accurate, and the workmanship in general, as might be expected, not approaching to any degree that of to-day.

The safe had many defects. The castings mentioned above were cut away on the hinge side of the door for the lodgment of the hinges. The hinges were made with an interlocking lug or boss that closed in back of the frame. The construction was bad on account of the added metal which tended to conduct heat into the interior of the safe, and the weakening effect which it had

on the frame on account of the metal that had to be cut out in order to provide space for the hinge.

The recent advances in the construction of fire-proof safes consist:

First, in the Matter of Patterns for Door and Frame Castings.—These patterns have been revised and reconstructed at large expense with a view to securing a better fit between the door and its frame. Foundry practice has improved to such an extent that castings can now be secured with much less variation in size than formerly. To keep pace with, and to take advantage of, this advance in the art of making castings, it was necessary to reconstruct the patterns. When this was done seven years ago, the tenon and groove and the interlocking-jamb features were incorporated in all of them that had not previously been so constructed. We are now using moulding machines in the making of many of our door and frame castings, which has enabled us to further reduce the limit of variation in the size of the castings themselves and to fit together a door and frame with the smallest possible allowance for variation in size of castings.

Gray iron castings can now be made that will withstand a high degree of heat without warping. In the production of our castings we use those materials which have been determined by experiment to be the best adapted to the production of a casting of uniform size, strength and rigidity.

The effect of the close-fitting door, together with the features of the tenon and groove and interlocking flange, upon the relative fire-proofness of the safe is great. A closely fitted door braces and reinforces the strength of the frame, while a loose-fitting door adds the weight of its overhang to the frame and weakens it in direct proportion to the looseness of the fit.

Second, the Framework.—The old style band hoop or frame has been superseded by the solid welded angle-frame. The front frame supports the jamb casting and provides a fastening for the hinges. This angle is a vast improvement over the old style band or bar frame.

The manner of welding the corners is of the greatest importance. We have found by experiment that the best and strongest results can be obtained only by the hand method of welding. After the angles have been mitred at the corners the edges to be joined are hammered out hot by hand, so that they

will overlap each other when bent. The actual welding operation is then performed by hand and the strength of a corner so produced has been found by test to equal in nearly all cases the strength of a solid section of the angle itself—a result which we have found impossible to arrive at by any other method.

The outer section of the safe has been strengthened by reinforcing wherever experience has shown such reinforcement to be necessary. At the same time no unnecessary weight has been added. In fact, any weight that does not add proportionately to the strength of the whole structure is a serious detriment in case of a fall. In the modern safe we provide angles and bars between the front and rear frames. The angles are placed at the corners and the bars midway between. These are securely tied to the frames of the safe and provide additional means for fastening and supporting the outer steel wall. This outer steel wall, as well as the inner steel wall, is made heavy enough to properly support and retain the fire-proof composition, and light enough so as not to add any superfluous weight to the safe.

The proper proportioning of the parts relative to each other, and to their various functions, is a matter that has been given the most careful consideration in the development of the modern fire-proof safe.

The doors are hung on malleable iron ball-bearing hinges. These hinges are fastened on the outside. The introduction of the interlocking flange in the rear of the door has made it no longer necessary to mortise them into the door and jambs. The burglar would gain nothing by knocking them off. The ball bearings by their resistance to wear maintain the door in its proper relation to the frame, and provide the additional feature of ease of operation. The outside hinge as now used makes it unnecessary to cut away part of the strength of the frame as was formerly done while the inside hinge was used.

The operation of the bolting mechanism has been simplified by being made more direct. The locks now used on the outer doors are of the combination type. They are protected by steel plates to prevent drilling and the arbors or spindles are shouldered to prevent driving in or pulling out.

An additional device is also provided that will automatically hold the bolts in the locked position in case the lock is in any manner rendered inoperative.

Those features in their best form are all of comparatively recent origin, and have added much to the value of the protection afforded by the modern safe.

The inner steel doors of fire-proof safes have heretofore been guarded by ordinary key locks. The same is true of the small cash boxes usually found as a part of the cabinet equipment. In the very near future the Herring-Hall-Marvin Safe Co. will equip all of its inner doors and cash boxes with changeable key locks, thereby adding greatly to their security by the facility with which keys may be changed by the user.

A complete line of steel interiors fitted with the most improved modern filing devices will shortly be completed and placed upon the market by this same company. This will be a great advance over the type of interiors now in general use.

To the above-mentioned improvements have been added numerous other minor refinements that result from better mechanical methods, modern factory organization, and thorough inspection.

There has lately been placed upon the market by the Herring-Hall-Marvin Safe Co. a modern safe fitted with a built-in system of electrical protection. This safe may be connected to a central station system or may be fitted with a local alarm. In appearance it resembles closely the ordinary fire-proof safe and is a marked improvement over the types of electrically protected safes now in use, which depend for their security upon a separate electrical cabinet encasing the safe.

In this new safe the electrical circuits are built into the safe itself. The circuits are so arranged that any attempt to wrongfully gain entrance to the safe by the manipulation of the locks, by drilling, or by any other method, will cause an alarm to ring.

The circuit connecting the safe with the alarm is a closed one and is so arranged that it cannot be tampered with without causing the alarm to ring. The Herring-Hall-Marvin Safe Co. owns and controls the patents covering this type of construction.

The so-called burglar-proof safe or vault has been improved and perfected in many ways in the last ten years.

The development of the burglar-proof safe depended in a large measure upon the development of the steel industry, and to a great extent also upon the development of locks. Until such time as really burglar-proof locks had been perfected no great

advance could be made in the development of the burglar-proof safe or vault.

The burglar-proof safe of to-day must be drill-proof, it must be fitted with a door that seats so closely into the opening provided for it that no liquid explosives of any kind can be forced between the door and the jamb.

Its bolting mechanism must be of sufficient strength to retain the door in its seat and it must be controlled by locks, the operation of which will leave no opening through the door for the introduction of explosives.

The modern method of arriving at these conditions differs greatly from the attempts that were made years ago. Drill-proof steel, as formerly used, consisted either of Franklinite, which was cast or poured between two solid metal walls and allowed to harden in place, or strips of so-called spring steel laid between two retaining plates of soft steel.

The drill-proof steel used in the construction of the modern burglar-proof safe or vault is what is known as five-ply steel. It consists of alternate layers of hard and soft steel rolled and welded together, the result being a plate that will, when tempered, successfully withstand the hardest drill and will yet retain enough tensile strength to resist the crushing and rending effect of modern explosives. This steel was not available in the older types of construction. It is now in general use.

The most recent improvement in burglar-proof construction is the round-door safe, and the round-door bank vault. The increased closeness of fit that can be made in a round door between the door and jamb, and the possibility of actually grinding the door to its seat, makes this type of construction the highest in existence to-day.

The amount of protection afforded by the lighter forms of construction that were in use fifteen or twenty years ago, is in the light of present-day developments very inadequate. It is only in recent years that the jambs, or the union between the door and the frame have been polished. Earlier than this the machining was roughly done, and if too much opening was left a free use of putty and paint at least made an appearance of a fit.

All this has been changed, and for the past eight or ten years no burglar-proof door has been made by a reputable builder that

does not show the polished metal on the edge of the door and jambs.

There are two general types of construction in use to-day, one being characterized as laminated construction, consisting usually of alternate layers of open-hearth steel and five-ply steel, and the other being what is known as insulated constructions. This latter contains an outer section of cast steel containing in its construction insulating materials in which are embedded drill-proof rods or bars, and an inner section of laminated construction.

The intention in this latter construction is to eliminate the danger of burning by the electric arc, by Thermite, or the oxy-acetylene flame.

There has been much discussion as to the possible use of these agents by the burglar. It is a fact, however, that long before they were considered in this connection the modern builder of bank vaults had made many experiments and had devised ways and means of overcoming practically all the danger from these sources. Many of the older types of bank vaults, however, are not as well protected in this way as are the recent ones.

The general tendency was up until recent years, to build vaults very light in construction. An eight-inch door was considered a very heavy one. Now doors are built as thick as twenty-eight inches, and one is now in course of construction in the factory of the Herring-Hall-Marvin Safe Co. that will be, when completed, thirty-eight inches thick from the outer face of the door to the inner face of the bolt frame plate. The total thickness over all from the surface of the operating mechanism of the door to the extreme inner surface of the glass door covering the bolt work will be sixty-one inches.

The greatest advances, however, in recent years in burglar-proof construction have been the result of the application of up-to-date mechanical methods in their production.

Modern drill-proof steel gives absolutely adequate protection against the use of the drill. Steels formerly used and incorporated in the construction of bank vaults were not, however, drill-proof to the extent that this quality exists in the present-day steels. These older types of vaults therefore are not as thoroughly burglar-proof in this sense as are the more modern ones.

When the vault manufacturer succeeded in producing a bank vault that would successfully withstand the use of a drill, he

found that his vaults were subjected to attack by the use of the wedge in the crack of the door itself. The closeness of the fit of the door did not in any way interfere with the successful use of the wedge.

A system of interlocking jambs was devised which in a measure would prevent the springing of the frame away from the door, and this reinforced by the more recent overlapping flange, which makes it impossible for the burglar to use a wedge on one of these modern doors, has eliminated entirely this source of danger. No owner of a modern bank vault need fear either the drill or the wedge.

The same security exists in reference to lock spindles that are used at the present time. Formerly these were carelessly fitted and openings could be found around them for the introduction of liquid explosives. Now they are so carefully ground into the doors that it is impossible even with pressure to force around them any known liquid explosive.

The same close fit is now also made of the door in its seat. Every modern bank vault entrance is subjected to what is known as the water test, and the door must fit so closely into the jambs that it will resist the passage of water between the door and frame.

The operating mechanism of the bolt work has been greatly improved. Formerly the bolts were operated through a system of levers and bell cranks that were indirect in their action, and were frequently the source of great inconvenience to the user. The modern boltwork is operated through gears and racks, and is so balanced in its action that very little effort is required in locking and unlocking.

The hinges are better adapted to the service expected of them. In all modern vaults the doors swing on hinges fitted with ball and roller bearings of the very best design, workmanship and materials, making a door of many tons weight so easy to operate that a child can swing it in and out, yet so perfectly balanced that it will stand at any point. These bearings are fitted with means of adjustment to compensate for wear.

The pressure mechanism for seating the door into the jambs has been improved in design and construction.

The inner surfaces of the front jambs on all of the best examples of the modern doors are brought to a uniform plane to

provide a perfect seat for the locking bolt wedges. These wedges have an inclined inner face parallel to the bevelled bearing face of the bolts themselves. These bearing faces are made as broad and large as possible, and the wedges are separately adjusted and fitted under the bolts so that when the door is seated and the locking bolts thrown the holding and retaining power is uniformly distributed throughout the entire system.

The modern means employed for binding the locking bolt mechanism to the body of the door consists in tapering or conical bolts running well into the body of the door, each bolt separately fit to its seat, and all binding the bars through which the locking bolts operate firmly and securely to the door. This method of fastening and fitting makes the door with its bolting mechanism an indivisible unit; the holding and retaining power equalling the great strength of the solid section of the door itself.

In the older types of construction revolving bolts were used. The fit of the doors was so imperfect that it was feared that the burglar might pass a saw through the crack of the door and saw off the locking bolts.

The structure guarded by the door, or entrance, which in common practice is called the lining, has been strengthened and improved upon in many ways. The modern lining is built up of alternate layers of steel plates. A combination is made of plates of unusual toughness and high tensile strength, with drill-proof plates of five-ply welded iron and steel, all bound together and protected at the outer and inner corners by massive steel angles. The plates of adjoining layers are laid at right angles to each other and the size of the various plates are calculated so as to break joints. The surfaces of all plates are rolled to perfect planes and the edges of plates and angles are ground to a liquid proof fit. The angles at the corners are welded into three-way members that effectually bind the vertical and the top and bottom faces of the lining together.

The steel plates used in the construction of the modern vault will resist the penetration of the best drills. The high tensile plates will successfully resist all explosives, and the ground joints prevent the introduction of liquids.

Steels of the quality in use to-day were not obtainable in the earlier years of the industry. Machinery and machining methods were crude, and factory organization as it exists to-day with its

team work and all of its multitudinous aids to rapid and perfect production was undreamed of.

All the foregoing that relates to improvements in bank vaults applies with equal force to burglar-proof safes. The same high-grade materials are used and the same careful methods applied in the construction of even the smallest burglar-proof chest.

Burglar-proof safes are now made both of the laminated and also of the later solid manganese steel variety that are absolutely impervious to any known method of attack.

Coincident with the modern development of the safe and bank vault industry was that of the profession of the Bank Vault Engineer. The industry owes much of its progress to the work done by the pioneers of this profession William H. Hollar, John M. Mossman, Geo. L. Daman, E. A. Strauss, Frederick W. Holmes, Benjamin F. Tripp and George L. Remington.

The days when might was right have given place to the later days when right is mighty. The safe industry stands ready to protect your valuables not only against fire and the burglar but against organized mob violence as well.

Physico-Chemical Studies of Rubber. F. W. HINRICHSSEN. (*Zeit. Angew. Chem.*, xxiii, 1345.)—The more recent contributions to the chemistry of rubber are summarized. The author regards the constitution of the hydrocarbon as being definitely settled by the researches of Harries, and refers to the possibility of synthetic production. The determination of the molecular weight of the substance present in the globules of the latex has given results which indicate that this substance is not the comparatively simple compound supposed by Weber, the molecular weight being about 3000. The rubber is undoubtedly present in the latex as a typical colloid. The recent work on the optical activity of the rubber resins and on vulcanization by sulphur chloride is referred to. The reaction in vulcanization appears to be a true chemical reaction, but in presence of moisture, it is accompanied by the formation of sulphur which is adsorbed by the rubber. The maximum addition of S_2Cl_2 is represented by the formula $(C_{10}H_{16})_2 S_2Cl_2$.

Very Sensitive Selenium Cells. F. C. BROWN. (*Phys. Zeit.* xi, 481.)—Selenium cells of great sensitiveness can be prepared by using a mixture of two modifications of selenium, viz., the amorphous variety obtained by dissolving vitreous selenium in potassium cyanide and precipitating with hydrochloric acid and the red crys-

talline product prepared from the former by dissolving in carbon bisulphide and exposing the solution to direct sunlight. A mixture of 10 parts of the amorphous and 1 part of the crystalline selenium is rubbed to a paste with ether, pressed in a mould around wires of German silver, heated for 5 hours at 170°C . and then cooled. The resistance of the product shows great variations (5×10^7 to 1×10^{10} ohms in the dark). The ratio of the conductivity in the light to that in the dark, i.e. the sensitiveness, ranges from 30:1 to 300:1; and varies considerably with the temperature from 80:1 at 39°C . to 300:1 at 3°C .

Action of Ultra-Violet Rays on Certain Carbohydrates. H. BIERRY, V. HENRI, AND A. RANC. (*Comptes rendus*, cli, 316.)—Reducing substances are formed when solutions of certain polyoses (sucrose, gentianose, raffinose, etc.) and glucosides are exposed to ultra-violet rays. It is found that *d*-fructose, similarly treated, undergoes a molecular degradation, producing formaldehyde and carbon monoxide. Such a decomposition of this sugar has not been effected previously without the aid of ferments or chemical reagents.

Testing the Capacity of a Soil to Decompose Cellulose. H. R. CHRISTENSEN. (*Zent. Bakt. u. Parasiten k.*, xxvii, 449.)—Fifty grammes of dry soil are placed in a 300 c.c. Erlenmeyer flask so that it forms a level, loosely packed layer covering four-fifths of the bottom of the flask. On the uncovered part water is run in from a pipette until the soil is nearly saturated. Two strips of ash-free filter paper are laid on the wet soil. After some time the cellulose is attacked and is transformed to a viscous, gray slime or mucilage, in which the microbes are contained. When mould fungi effect the decomposition, a black coloration is produced, but there is no mucilage.

Metallic Thorium. CHAUVENET. (*Assoc. Franç. pour l'avancement des Sciences*, Aug., 1910.)—The author attempted to prepare metallic thorium free from oxide by using metallic lithium in place of sodium for reducing thorium chloride. By heating the mixture in an iron boat in a quartz tube from which air was carefully excluded, a product containing 96 to 96.6 per cent. of metallic thorium was obtained. This, however, contained 3.2 per cent. of thorium oxide which could not be removed. A purer product, 96 to 97 per cent. of metallic thorium, was prepared by heating thorium hydride (obtained by heating together thorium chloride and lithium hydride to 600°C .) in a vacuum of 10 mm. The metallic thorium thus obtained is black; it is not oxidized by air or pure oxygen at atmospheric pressure, but is oxidized by oxygen under pressure. It takes fire with a luminous flame in fused potassium chlorate. It combines with chlorine to form thorium chloride, ThCl_4 , with the liberation of 339.43 calories.

THE SELECTION AND TREATMENT OF ALLOY STEELS FOR AUTOMOBILES.

BY

MR. HENRY SOUTHER,

President Souther Engineering Co., Hartford, Conn.

*(Presented at the meeting of the Section of Mining and Metallurgy held
Thursday, October 20, 1910.)*

[This paper treats of the various kinds of alloy steels and their applications in the automobile industry. Attention is called to the necessity of selecting steels which will do most efficiently the particular work for which they are intended.]

A POPULAR remark during the last few years has been to the effect that the steel business has advanced and changed rapidly and that the incentive is found in the manufacture of automobiles. This condition still continues and the evolution within the construction of the car itself is no less rapid. Design, materials, style and selling methods are all involved.

Curiously enough, it would seem at first glance, the choice of materials is involved in all of these four branches of the industry and not in the one or two as would seem natural.

The reasonable use of materials is to be the theme of this paper. Many considerations are involved in looking back to the beginning of the automobile industry and it seems necessary to do this in order that the evolution may be followed as far as materials are concerned.

At the beginning every faculty of designer and builder was focused on the production of an operative machine. Materials were disregarded so long as they would help build the vehicle and were obviously steel, brass, aluminum or wood. All were too busy to regard the quality. Generally speaking there was available from the stand-point of the automobile builder Bessemer steel, open-hearth steel and cast or crucible steel. Variations within these classes were regarded as unimportant and heat treatment was an unknown term: certainly only theoretical at the best and therefore useless to a practical man.

Now these same men have among them those who state that the heat treating department of the works is the most important

of all. This is not so with all yet; there are some who still balk at talk of critical points, recalescence, pyrometers and the like. The evolution is rapid however and this class will soon disappear.

After a year or two the cars operated very well; at least well enough to run long enough to break parts, crank shafts, axles and steering parts. Then a little attention was directed toward steel. There seemed to be no clear idea of a cure. If a steel part broke with an appearance of brittleness good old wrought iron was tried as a sure cure. If bending occurred tool steel was tried in some cases and medium carbons (0.50 per cent.) in others; it being understood that high carbons were stronger but brittle. The natural or annealed state was the only one known to the automobile industry at this time.

At about this time nickel steel was mentioned as a possibility. It had been used, or as some said "advertised as used" for bicycle construction. But generally it was regarded as something fancy and not worthy of the consideration of hard headed men. It was expensive, hard to work and no good anyway in the opinion of many.

So when alloys came along in earnest and were offered systematically by steel agents they had a hard time making any progress. The high prices quoted were laughed at. There seemed to be no chance that alloys would ever be given a fair trial. After some little time and persistence by the steel agent, alloy steels were tried and proven good even at 15 cents per pound. Some designs required alloy steels to stop breakage the result of small dimensions, sharp corners where fillets should be and similar mistakes. In this way the alloy, or perhaps the high quality carbon steel, had a chance to make good in a spectacular way. These instances helped the spread of high grade steels until now the pendulum has swung too far and alloys are used where they need not be and money is thereby wasted. There is indication of a notion that an alloy steel is a cure-all; and that if needed in one part that it must be a fine thing in all parts.

Unfortunately the art of heat treatment has not spread as fast as alloy steels have and many cases exist where very expensive steels have been put into cars in an annealed or forged condition; which is absolutely unreasonable. The alloy steel is no cure-all and must be used intelligently, if any compensation for increased cost is to be realized.

A case in point is found in an engine crank shaft. It is large for the duty. If it is made of an alloy treated up to 100,000 lbs. per sq. inch or more, when 60,000 lbs. would suffice there has been no gain to the automobile and there has been a money waste. It is not generally understood that a high elastic limit adds nothing to the stiffness or rigidity of a part. It does add to resistance to fatigue but with the case in point the shaft is over size and fatigue cannot take place in the absence of bending.

The same general condition applies to gears of all kinds. It is not the rule, by any means, that gears of smallest section are made of the strongest steels. This should be so and is so in one very marked case. On the other hand many very heavy gear sets, duty considered, contain steel of greatest strength and all out of proportion to necessity. This is unreasonable as it is obvious that strength should be a function of design. A bridge or a building is calculated to a nicety, as yet automobiles rarely are. Knowledge of steel is not yet sufficiently wide-spread. The history of the automobile is short and there has not been time enough to disseminate knowledge of so many special steels and special treatments. Then too an air of mystery regarding special steels and secret treatments has been fostered in some circles in such a way as to befog the issue and retard the spread of truth.

At the beginning of the automobile art the steel industry was old. Alloys and heat treatments were no mysteries to the steel metallurgist. Makers of armor plate, gun tubes, propeller shafts and other important specialties had been using many grades of steel and many treatments to meet peculiar needs. This knowledge had not and does not spread readily to makers of small arms, sewing-machines, bicycles or typewriters and they all need it to some extent.

Some reason for this is found in the "old fashioned" selling methods of many steel companies. Most salesmen are not furnished with accurate knowledge of the steels they sell or if they are they are forbidden to use such knowledge on possible customers. They use a line of argument that contains no metallurgical information and is too often far from the truth. There are large numbers constantly engaged in this way so it is no wonder that little real progress is made by aid of the salesman. Fancy names and fancy prices for common steel is their specialty.

It is a pleasure to feel that such methods are giving way to

others and better. The steel works engineer, metallurgist or chemist is now placed in contact with the consumer. His wants are learned and supplied without secrecy or mystery. The opportunities of change and improvement are pointed out and advance in the art will be rapid. As it is now there is but little knowledge, among consumers, as to the relative importance of analysis and heat treatment or of the importance of casting, rolling, hammering and cold working of steels. Consequently many consumers are in doubt as to what to believe, the truth as expounded by the conservative metallurgist or the near truths about the special alloys of the salesman.

Before taking up the finer steels it is well to study the history of what preceded them in the automobile art.

At the outset carbon steels were mostly considered and known as machine steel. Such steel was available and cheap, or at least low in first cost. Such steel is not always cheap, as much of it tears in machining to such an extent that work is ruined or will not permit the cutting of a thread at all because of its softness. Such machine steel is of about the following composition. It is not strictly speaking machine steel but there is so much of it on the market, so called, that it must be recognized. Carbon 0.08 to 0.13 per cent., phosphorus 0.08 to 0.10 per cent., manganese 0.40 to 0.60 per cent. and sulphur 0.06 to 0.08 per cent.

Machine steel, so called, as found in steel warehouses is not all alike by any means. This lack of uniformity is discovered by the user whose judgment usually is that the steel is no good anyway and does not behave twice alike in the machine shop.

The best machine steel, then existing, in stock, was of about the following composition with carbon from 0.18 to 0.25 per cent., with other elements like the foregoing analysis. Such steel machines smoothly and cuts a keen thread. A slight increase in carbon coupled with the other elements given makes a very marked difference in machining quality. A third quality of machine steel found on the market at the time in question was between the other two in carbon contents and much higher in manganese, analyzing about as follows: carbon 0.12 to 0.18 per cent., phosphorus and sulphur about 0.08 per cent., and manganese from 0.60 to 0.90 per cent. The manganese contents made for smooth cutting and the steel was a good one for carriage axles, which must be machined very rapidly, and other similar uses.

These machine steels were all characteristic of Bessemer output and were put into the early automobiles. They answered the purpose until the machines began to wear fairly well and poor (weak) design developed. High carbons were tried and wrought-iron was tried all in a blind unreasoning way. Some troubles were cured but some could not be cured by any change of material known at the time. The details of design were such as to cause failure with any material. Failure was delayed but not prevented.

One grade of steel, common then and now, known as screw stock deserves notice, as it plays a more important part in automobile construction than it ought to. It is close to machine steel and is sometimes sold as such. The approximate analysis is as follows: carbon 0.08 to 0.12 per cent., phosphorus 0.12 to 0.18 per cent., manganese about 0.50 per cent., sulphur about 0.10 per cent. The dominant element, that makes for easy cutting, is phosphorus, which is twice normal for Bessemer steel. More steel of this quality than of any other composition, can be put through an automatic screw machine in a given time, and turn out a fine product. But the drawback is phosphorus, which causes brittleness in steel and makes it unsafe for automobile construction. Except in screws of no importance or parts carrying no load, it should not be used. Important screws are now made of alloy steels heat-treated. Connecting-rod and engine-base screws for example. The above screw stock after casehardening, as it often is, shows a coarse brittle grain even with the best of treatment. No hardened parts of this quality should be used.

At the present time little steel high in phosphorus finds its way into automobile construction. Basic Open Hearth steel is mostly used and this is uniformly below 0.04 per cent. in both phosphorus and sulphur.

This quality of steel in the vicinity of 0.10 per cent. carbon machines with the greatest difficulty, consequently a standard machine steel has been developed containing enough carbon and manganese to offset the softness. The analysis is as follows: carbon 0.20 to 0.30 per cent., phosphorus and sulphur not over 0.04 per cent., manganese 0.40 to 0.70 per cent.

This quality of machine steel handles well in every stage of manufacture and responds to heat treatment in a way that makes the product suitable for many parts of a car. This steel is a fine steel for the general run of drop forgings. It is suited for the

important members of low priced light cars, and for carbonized and hardened bevel and transmission gears in such cars as are of low power and generous gear design.

With the general use of basic open-hearth steel this type of machine steel is bound to be generally adopted. Its usefulness is very wide-spread and its cost as low as any open-hearth steel. The extra expense that is warranted is the care necessary to free from seams or other physical defects. This is done by the steel maker or the one who prepares the billets or bars for shipment. Freedom from seams insures a sound product at the finish of an expensive series of operations and is worth paying for.

Simple heat treatment will give an elastic limit per sq. inch of 60,000 lbs. This is the result of quenching at about 1500° F. in oil, then partially annealing at 800° or 900° F. Such strength is accompanied by good refinement of grain and corresponding toughness and capacity to resist shock and repeated alternate stress. The machine steels previously mentioned would not be safe under the foregoing treatment or any other; as refinement of grain does not take place to a satisfactory extent in the presence of so large a percentage of impurities.

Without a fine grain development in steel fatigue takes place very rapidly. In using this term "fatigue" the same phenomenon is in mind that is often referred to as crystallization. Cold crystallization does not take place. It is a different physical change and will be discussed later.

About the years 1893-1894 bicycle parts often failed (to quote) "while riding along the smoothest road." The fractures did not exhibit coarse crystals as a rule, particularly in cold-drawn spoke wire or tubing. But in every case there did exist an opportunity for concentration of strains, bending or vibration, at a limited section. These failures led to studies of fatigue conditions.

It was commonly thought by well trained mechanics that the softest toughest steels would resist longest under these conditions simply because of the tough quality. This was found to be not so. Tough and soft steel is weak steel having an elastic limit per sq. inch from 30,000 to 40,000 lbs. A good grade of forty (0.40 per cent.) carbon steel may have an elastic limit of 50,000 or 60,000 lbs. Such steels in an annealed condition were compared under such circumstances as to produce a fatigue break. The dead or actual load used in comparison was the same. This

load was chosen to produce a fibre stress nearly as great as the elastic limit of the weaker steel, say 25,000 lbs. per sq. inch (about 84 per cent.). This stress was only 50 per cent. of the elastic limit of the stronger steel. The weaker steel, soft and tough, broke quickly after 20,000 to 50,000 alternations of stress. The stronger steel looked upon as being brittle and hard, endured say 400,000 alternations of stress, an increase not in direct proportion to strength and quite contrary to the characteristic of toughness as measured by elongation. It is evident that the toughness was not the controlling element under fatigue conditions and that strength as indicated by elastic limit was an important factor with some other element not obvious, playing an important roll. Such an element was sought in the crystalline structure. Such structure is fairly indicated by transverse fracture for the purpose in hand. The fracture of the low-carbon tough steel is course grained with crystals presenting large cleavage planes. That of the higher carbon, brittle steel, showed a close grained structure with no crystals having cleavage planes of conspicuous size. That is, the steel that endured longer was strong and fine grained. These were the controlling elements.

It is for this object that all heat treating processes are practised—to produce greater strength and to refine the grain. The most reasonable steel to use in automobiles is that which will respond best to treatment or that will respond sufficiently for a given purpose, dimensions and duty considered. There is no reason in selecting a steel that will not respond somewhere in proportion to the cost of the operation; that is, the improvement must be material. Neither is it reasonable to select a steel at great cost that will respond to such an extent as to be way beyond the necessities of the case.

The treatment necessary to give a steel depends somewhat upon the physical condition of the steel as received by the consumer or user. For example, it is quite possible and often happens that bars of steel reach the manufacturer of automobile parts in a very coarsely crystallized state, this being due to the last forging or hammering operation prior to shipment by the steel mill. If this steel is to be used by the parts maker without further drop forging or other heating operations, the steel must receive a thorough annealing. In the absence of such annealing operation, which will reduce the coarse condition of it to a

properly refined condition, a single heat treatment will not produce the expected results.

If, on the other hand, the bar or billet is to be forged, then this coarse crystalline condition matters but little and the annealing must necessarily follow the forging operation and for the same reason; to guard against a possible condition of coarse crystallization which will not be refined by a single heat treatment.

Our steel makers would do well to learn whether or not the consumer of the steel is to again forge. If not, annealing should be the final operation at the steel works in all cases. Otherwise, steel of good quality may not perform as well as it should.

It is not always possible for the steel manufacturer to know whether or not steel is to be forged again and, in view of that fact, it is the habitual practice of some of the steel mills to anneal as a final operation. No harm is done if the steel is again forged, and if not forged the steel is found, by the user, to be uniform in machining qualities and well behaved under heat treatment. Uniformity of machining quality is of far more importance in the eyes of the mechanic than is fully appreciated by many steel companies. Many thoroughly good qualities and shipments of steels are complained of and perhaps condemned because of the presence of so-called hard spots and bad cutting qualities. The machine shop cannot be expected to know that it is not the composition of the steel that is at fault and the steel maker should guard against such complaints by the relatively inexpensive operation of annealing.

These remarks apply very strongly to tool steels that are to be shaped into expensive tools, to spring steels and to the higher carbon steels in general. They apply in a lesser degree to the lower carbon steels but nevertheless are of great importance.

Many machine steels are condemned because tools are rapidly dulled in machining them and the complaint is, as a rule, that they are too hard to cut. As a matter of fact they are too soft to cut smoothly. They tear and cling to the point or edge of a tool and the cutting operation becomes more or less of a rubbing operation which creates heat and dulls the tool by softening it. Proper annealing, suited to the carbon, will correct this fault, but the machine shop manager cannot be expected to know this and probably has no facilities for annealing or other heat treatments in many cases.

Take an engine crank for example. Other considerations than strength influence the design. It must have ample diameter to furnish adequate bearing surfaces. It must be rigid and stiff. No alloy can increase this latter quality. A steel with 60,000 lbs. elastic limit per sq. inch is quite strong enough to outlast the engine. One of 200,000 lbs. elastic limit would make no better crank shaft under the assumed conditions and would cost more at first cost, in forge, in machine-shop, and in heat treatment. This is a fair example of unreasonable use of alloy steel.

To return to qualities producing endurance under alternate stress. A drop forging as it comes from the dies is likely to be in a non-homogeneous condition as the result of the process and at the best, because finished at a relatively high temperature, is likely to possess a very coarse open grain. If intended for a vital part this grain must be refined. It may be perfectly done by proper heat treatment, and it is done habitually by careful operators. The result is a homogeneous piece of metal. No other character of steel is fit to enter the construction of an automobile where it is potentially possible of much harm or much good. Carbon steels should be so treated; alloy steels must be, if fair value for money spent is to be received.

Alloy steels of expensive variety have been put into cars without heat treatment, just to say they were used. An alloy steel not suitably treated, that is in an annealed or forged state, is little if any better than good open-hearth machine steel in an annealed condition. Its endurance under fatigue test is low. Its elastic limit is low, and its structure as indicated by transverse fracture is bad. Such use of alloy steel is unreasonable and the only additional value obtained for the excess paid as compared with carbon steel is an advertising value.

On the other hand alloy steels suitably chosen and heat-treated have extricated many an engineer from real trouble. A driving shaft, having 60,000 lbs. elastic limit, for example, may have proven weak with good carbon steel. Because of the design of connecting parts a change in dimensions is often practically impossible. A solution is easy with a good 0.30 carbon, 3.5 per cent. nickel steel treated to 90,000 lbs. per sq. inch elastic limit, or if necessary a chrome-nickel of high carbon treated to 150,000 lbs. elastic limit. Such applications of alloys are worth all they cost and are reasonable in every way.

It is the alloy steel that responds best of all steels to heat

treatment. Results are obtainable that are nothing short of wonderful. Only recently a tensile strength of 300,000 lbs. per sq. inch has been reached. Coupled with such strength, say 200,000 lbs. per sq. inch, very great ductility is obtainable as indicated by elongation and reduction of area at section of rupture. Too great stress cannot be laid on this last item. It is the best measure, in a tensile test, of the degree of refinement of grain attained by heat treatment. Reduction of area will be slight if the crystals or grains are large. If the grains are large as already stated, endurance under fatigue will be little and endurance is beyond argument the most valuable asset of an automobile subjected as it is to shock and vibration at all times, while in motion, and to an extent beyond any other mechanism.

Attention has been called to the relative endurance of 0.10 and 0.40 per cent. carbon steels under fatigue test. Under the same dead load a specimen of 0.30 per cent. carbon, 3.5 per cent. nickel heat-treated will endure several million alternations of a 25,000 lbs. per sq. inch fibre stress, and a specimen of 7.5 per cent. nickel has endured one hundred million without rupture with the fibre stress at about 50,000 lbs. per sq. inch. The tensile tests give no indication of any such difference in endurance unless it be in the reduction of area coupled with a high elastic limit. These figures are always large with good endurance. The reduction of area is a measure of fine grain, so it would seem that this quality may be the most influential in determining endurance.

There is good chance for theorizing and reasoning along this line. With the theory of cold crystallization set aside, a reasonable cause for breakage must be found. Steel may be considered as made up of crystals which interlace and adhere. If a test specimen were made up of crystals whose faces equalled the diameter of the specimen, there would be the exaggerated condition of all adhesion and no interlacing. One cleavage plane extending across the specimen. It is easy to conceive that the separation of surfaces once started would jump at once across the specimen and rupture would occur. There would be only adhesion to overcome. It is equally plain that were the same specimen made up of an infinite number of crystals, that a separation started at the periphery would meet with an interruption before being of finite size; after which a fresh start might recur at another point to meet with similar interruption. In this way

an infinite number of starts would be necessary to bring about rupture. In other words there would be no chance for a continuous fracture along any one line or surface, and rupture would be delayed indefinitely.

A fibred piece of steel endures better than one not fibred although both may be of very fine grain. It is easy to conceive that if "fibre" is all the name implies, that an incipient fracture formed in one fibre could not continue across the space between fibres and would thus stop. Wrought-iron breaks under fatigue as in an axle or shaft. The fracture always shows crystals. Is it not possible that a fatigue break can take place only where crystals exist, and that because crystals are at a given section, fracture takes place there?

It is easy to understand how a progressive fracture may proceed along the faces of a series of crystals as in the splitting of granite by means of wedges driven into a row of holes. It is not easy to conceive the splitting of good fibrous hickory or elm except with and along the fibre. Splitting across the fibre is impossible, there could be no continuous fracture and therefore no rupture.

A fatigue break has been described as "progressive inter-molecular rupture." It would seem more probable to be "inter-crystalline" inasmuch as the molecules, of a given composition, are doubtless all of a size, regardless of heat treatment or physical treatment. On this theory, heat treatment would cause no difference in behavior under fatigue; which would be contrary to fact.

Another phase of fatigue is, that such breaks rarely if ever occur unless strains concentrate at or near one plane or section. If strains be distributed as in a beam of uniform strength, fatigue does not occur. A generous fillet or a taper retards fatigue almost indefinitely. A sharp corner causes it to occur very quickly.

Design and material both play an important part, and the two must be considered simultaneously if good engineering is to be attained. If a design be adequate with poor material, it is folly to buy better. If design be suited for the best, then only such may be used otherwise bending and breaking will occur at once. These statements seem too simple for reiteration, but it is a sad fact that both simple truths are violated in automobile construction.

There is one form of heat treatment as old as the hills, that is little understood by many that have practised it longest, namely, "casehardening." It is easy to turn out coarse or fine grained product. The fine grained is desirable (as in good tool steel), the coarse grain is not, as in burned tool steel. Too few realize that a low grade steel after carbonizing is no longer low grade. It has had money spent on it to improve it and if the low carbon was pure steel; the high carbon exterior, the result of carbonizing, is pure high carbon steel; therefore, good tool steel and must be treated accordingly.

No tool dresser would heat tool steel in boxes for ten hours at a temperature of 1700° F., then quench in water at that temperature and expect a tool to do good work. Yet this is exactly what is done in many otherwise well regulated plants, and the steel is blamed if the parts so treated are brittle. So treated the crystals are large; the steel is brittle.

If used for ball or roller bearings, the polished surface is friable and crystals spawl out thus starting pits and fractures. Suitable refining treatment improves this condition and makes a success out of a possible failure.

In casehardened parts two qualities of metal are to be dealt with, and the best practise demands treatment that will refine both grades. The interior of two are the original carbon and the exterior a carbonized layer of a higher carbon. The refining temperature of the lower carbon is higher and one treatment must reach this. The other temperature, correct for the high carbon, will not undo the refinement of the lower carbon. Thus by two treatments both qualities are fully refined and the composite structure is a good one. Alloy steels are subject to the same laws, and it is only necessary to be acquainted with the critical points of the various compositions to get the best results.

Transmission gears and main drive bevel gears are successfully made of carbonized steel, both carbon and alloy. The quality selected must be referred to design and duty. The duty of constant mesh gears running in oil is relatively easy if the dimensions be generous. The duty of clashing transmission gears is never easy and may be awful with a dragging clutch or careless manipulation by the car driver, and with clashing taking place under loaded or partially loaded conditions.

With equally good design the bevel driving gears do not need the same or as good steel as the transmission gears. It is com-

mon and good practice to make the large bevel gear of good carbon steel and the driving pinion meshing with it of an alloy steel.

The character of the treatment and resulting condition of the steel is of vastly more importance than the composition of the steel used. The best of alloy steel may be so handled in treating as to produce a weak and inferior part. Similarly by the best of treatment good open-hearth machine steel may be so well handled as to make a most excellent main drive pinion or other part.

It is true that the best must be produced for a few designs, but such are much in the minority at this time. There has been very little real close designing as yet. Empirical knowledge and data as to available materials are not yet exact. The art of heat-treating is not uniform and wide-spread among producers of automobile parts. A liberal margin of safety against uncertainty and non-uniformity is still the rule.

There is one practice in vogue among purchasers of alloy steels that does not seem to be founded on good reason. It is that physical requirements are specified in face of the fact that the steel is to be forged and heat-treated before being used in a car. Its final condition may bear no relation to its purchased condition. It may be carbonized for example. If steel be purchased on chemical analysis, the control is sufficient. With a known composition heat treatment may be intelligently directed without reference to original tension test characteristics.

If to be used as purchased, the matter is different and physical characteristics must be known. Elastic limit, reduction of area, elongation and tensile strength, in the order named, are desirable. If these physical tests be demanded then complete chemical analysis must not be. The steel manufacturer cannot produce if tied hand and foot. It is proper to specify chemical analysis as to impurity, that is phosphorus and sulphur, and also as to the dominant elements; nickel, chrome-nickel and so on. Even in these elements, manufacturing tolerances must be allowed. The practice of limiting all elements and coupled with physical requirements is wrong and often leads to the absurd situation of specifying an impossibility.

Even at the best, with the one writing the specifications knowing exactly what has been the practice in one steel works; it is not certain that in another works the result would be quite

the same. Some works use melting processes, casting methods, and forging methods that may easily modify physical characteristics as compared with practices in other works.

With a given quality of automobile in view, the number of grades of steel necessary to construct it is few, namely, a good all-around forging steel, a steel of slightly better quality to be used for gears, a spring steel and a steel suited for the pressed sheet-steel portions of it.

These steels, properly handled and heat-treated, each part for its peculiar duty, will produce a car of very high grade so far as the steel portions are concerned.

The car of extreme design, racing or otherwise, one that has been designed to strip off the last pound of weight, must be handled differently. Such a car is the exception and must be treated accordingly.

If an order be accepted at all under such unfair restrictions, it must be at an advanced price to cover probable difficulties. This simple fact is so well known to the steel producer that it is apparently absurd to state it, but it is not well known by the steel consumer and needs repeating for their benefit.

To sum up, the attempt has been made to indicate that alloy steel is better than plain carbon steel, that is, stronger and more enduring; that the design of some cars is such as to necessitate the use of the strongest alloy steel and that the design of others is such that an alloy steel is superfluous and money wasted.

That steel that is good for one purpose is bad for another and really that the term "good steel" is meaningless unless it be understood "for what." Pure steel, meaning freedom from impurities, means something always. It insures that such steel will give "good" results if the composition is suitable for a purpose and if the steel be treated to develop proper physical characteristics for the duty to be performed. Several steels (compositions), may be available that will perform a given function perfectly if properly selected and treated. No consumer need be tied to one maker, one composition nor one method of treatment. Several of each are always at hand that will give satisfaction. Reasonable use of steels can only be reached along lines as broad as this.

PROBLEMS IN CHEMICAL INDUSTRY.

BY

MR. J. T. BAKER,

President, J. T. Baker Chemical Co., Phillipsburg, N. J.

(Read at the meeting of the Section of Physics and Chemistry held Thursday, November 3, 1910.)

[The writer discusses the difficulties which arise when an attempt is made to apply on a commercial scale the results obtained from laboratory experiments. He is of the opinion that the chemist is best fitted to overcome these difficulties who combines with the scientific mind a certain amount of common sense.]

INDUSTRIAL chemists may well pride themselves upon being engaged in one of the most important and useful branches of the so-called sciences of the present day, and one that requires, in a certain sense, more science in the solution of its problems, than any other.

The question has often occurred to me, however, to what extent is chemistry a science, and is the solution of its problems a purely scientific work. After analyzing the subject carefully, I am lead to venture the statement that chemistry, as we understand it, is not a science, in the strict sense of the term, although it cannot be denied that the enormous advance that has been made in the field of chemistry during the past century, is due in a measure at least, to what is known as scientific investigation and the application of scientific principles. Much of the success, however, if not the largest part of it, is due to the application of what is known as common sense, in contradistinction to so-called science.

Some one has defined science as "organized common sense," and this definition, to a certain extent, is true, but the common sense that I refer to is that which is, so to speak, unorganized, and follows no given rule, but occasionally arrives at a conclusion in a problem, without any definite reason, except it be on the plea, that all great discoveries are the result of accident.

Taking the definition of science as organized common sense, or to use another expression, as systematized facts, this definition

also implies the further use of knowledge thus systematized, and the distinction between a scientific and an unscientific mind, is that the former adheres to a system and applies it, or attempts to apply it to various problems, while the unscientific mind follows no definite line of action, and arrives at results by accident or by good luck at guessing.

On the basis of the above definition of the term science and what it implies, it is evident that the most perfect science will be that in which the systematizing of facts is most complete, and the degree of perfection will be determined by the extent to which the system can be applied and followed. A perfect system is one that is based on a well-defined principle, in which every step is an application of this principle. In this respect it will be found that mathematics is the most perfect system, for here the system is so perfect that its principle can be applied and followed to an unlimited extent. The conclusions reached are absolute and hold good for all time and under all conditions. This is pure mathematics and it is pure science.

In the applied sciences, however, the systematizing of facts is not so complete, and in consequence the systems are not perfect, and can therefore be followed only to a limited extent. The avowed principle of the system and the conclusions reached do not agree, although in some cases the disagreement may be so slight as to be insignificant. Mathematical astronomy affords an example of the most perfect system of applied science, for here, while the systematizing of facts is not absolutely perfect, and consequently the conclusions are not absolute, they are so nearly perfect that the conclusions reached may hold good for thousands of years to come. The variations may be so slight as to be almost infinitesimal, but as long as the conclusions are not absolute, the system is not perfect. In the final analysis the scientific mind fails, and the problem is solved by the unscientific mind, which makes a guess at the result by striking an average.

The absoluteness of pure mathematics as a pure science, and the approximate absoluteness of the science of astronomy, may be explained by the fact that one factor only is taken into consideration in mathematics, namely, that of the relation between objects expressed in symbols, the physical properties of which are entirely ignored, while in astronomy, it is the relation between planetary bodies, the physical and chemical properties of which, however

much they may affect the final results, are also practically, if not entirely, ignored.

In fact, as we proceed to explain science in general on this basis, and apply the explanation to the so-called sciences that involve factors whose physical properties must be taken into consideration, it will be found, as the number of factors increases, that the systematizing process becomes more difficult and impossible, while the purity and accuracy of the science decreases accordingly. This will be observed as we pass from astronomy, where the factor is only one, or practically one, to mechanics, physics, chemistry, geology, biology, psychology, etc., the factors of which increase, while their accuracy as sciences decreases in the order named, until we reach sociology and theology, where the factors, consisting entirely of the vagaries of the human mind, become so numerous and antagonistic, that any systematizing whatever is practically impossible, and to these the term science has consequently no application.

It will thus be seen that the term science when applied to the various concrete sciences, has a very limited application, depending upon the number and complexity of the factors involved, and the pursuit of any of the so-called sciences in which the factors become numerous, would soon come to a stand-still, if it did not include the assistance of the unscientific mind; because a multiplicity of factors gives rise to problems, the solution of which is accomplished not so much by science as by empiricism. The tendency of the scientific mind, trained as it is, to look at problems along well-defined lines, in obedience to some system or law, is to ignore conditions and suggestions that do not seem to conform to these laws, with the result that valuable facts are often overlooked. The tendency of the unscientific or practical mind is to go to the other extreme, and ignore laws and systems, and try any suggestion that chances to come along, with the result that while much valuable time and labor may be lost, the loss is fully compensated by a few valuable successes.

I think it is safe to say that it is to the unscientific or practical mind that we are indebted for discoveries in the field of science, for it is only as we deviate from the well-known and familiar paths laid down by the scientific mind, that we stumble upon and discover new facts, and while the unscientific mind stands astonished and at a loss to know what to do with the dis-

covery, it remains for the scientific mind to lay hold of the novelty, and find a place for it in some general system of things. It has been said that the difference between a discoverer and an inventor, is that the discoverer is one who uncovers some new thing which he cannot make use of for lack of knowledge, while the inventor is one who takes the novelty, and by use of his accumulated knowledge, is able to recognize and make use of it, by means of a so-called invention.

While science may be defined as the systematizing of facts, the ultimate object of the system is to arrive at or hypothecate, if necessary, some law that will not only satisfactorily explain the facts, but will also enable us to deduce from the law new facts, or in other words to predict new facts or events. Pure mathematics affords the best example of this ability to predict or make deductions, for its deductions are without limit. Mathematical astronomy affords the next best example, for its deductions, or predictions, relating to the position of planetary bodies, can be made thousands of years in advance.

Prediction may therefore be considered a criterion of pure science, and the purity of a so-called science may be measured by its ability to predict, and this depends upon the absoluteness of the law or principle upon which the predictions or deductions are made, for where there is more than one principle involved, the deductions must be more or less antagonistic. In pure mathematics there is but one law or principle,—“The whole equals the sum of its parts,” and although there may be many corollaries to this law, the deductions are absolute and there can be no antagonism. In astronomy also, there is practically but one law or principle, the law of gravitation, expressed in mathematical terms, and the deductions or predictions therefrom are almost, if not quite absolute. The absoluteness of a principle implies absolute consistency of its application, for any deviation therefrom must necessarily involve the application of other principles. Pure science therefore is a system that involves an absolute principle and absolute consistency in its application.

Now with this understanding of what constitutes pure science, let us turn to the so-called science of chemistry—does it involve but one law or principle, and do we or can we consistently apply this law to the various problems encountered?

Up to the time of Dalton it is well known that the study of

chemistry was in a more or less chaotic condition, but after Dalton annunciated his so-called "Atomic Theory," and the same was generally accepted as a working basis, if not as a fundamental law of nature, chemistry became known as a science. Why? Because here was a fundamental law or principle that was considered absolute, and could be consistently applied, with the result that absolute deductions could be made upon the strength of it, and new facts or events could be predicted. Thus we can predict that if the atomic proportions of Cl and H are as 35 to 1, then 35 parts of Cl combined with 1 part of H will produce 36 parts of HCl whether we take grains, pounds or tons of the materials. We can predict that whatever quantities we can combine in chemical affinity, we shall find the same quantities in the resulting compound, and in doing so we have predicted a new fact or law known as the law of the "Conservation of Matter." By a combination of various laws deduced from the fundamental law, we get the law known as the "Periodic Law," from which we can predict new and heretofore unknown elements.

In so far therefore as the law of the Atomic Theory is applied in making deductions therefrom, and in predicting new facts, to that extent, we may honestly say that chemistry is a pure science. But in chemical investigation, in research work, and in chemical industry, etc., do we or can we apply this law to existing conditions and to the problems that confront us? Working on a small scale, where the only object is the demonstration of the law, the application may so closely approximate the law, as to warrant us in saying, on the basis of probability, that the law is applicable, but when the law is applied on a larger scale, as must be the case in chemical industry, its limitations become very apparent. It would be difficult if not impossible to mention a single instance, where it is not necessary to alter calculations based upon deductions from the law, in order to obtain satisfactory results. Even the atomic weights, upon the application of which the law is based, are not absolute, and it is therefore self-evident that any deductions therefrom cannot be absolute. These slight inaccuracies experienced when working on a small scale are conveniently attributed to "experimental error," but in operations on a larger scale, particularly in chemical industry, the discrepancies are very marked. Just one example will suffice to illustrate the failure of the law in its application—the manufacture of HNO_3 for in-

stance. The law would require the combination of 172 parts of NaNO_3 with 98 parts of H_2SO_4 , and on a very small scale in the laboratory, these proportions might give results approximately accurate, but on a large scale using cwts. or tons, these proportions will not give accurate results by any means. That is not to say that the combination takes place in any other proportion than those laid down in the law, but that the proportions required to produce the calculated results, are not the same. Here the deductions of the scientific mind fail, and the unscientific minds steps in and by experimenting and guessing, finally discovers that 95 parts of NaNO_3 instead of 172 must be combined with 98 parts of H_2SO_4 to produce satisfactory results. The proportions thus determined upon, may then be accepted, to a certain extent, as a working basis for the use of the so-called scientific mind in working out future problems of a similar character.

Here we see an illustration of the fact above referred to, that discoveries are made by the unscientific or practical mind, while the scientific mind endeavors to systematize the discoveries and thereby formulate laws for future use. Both qualities are generally combined in the same individual in varying degrees and are essential for success in any line of work, for discoveries, unless they can be formulated into some system from which we can make deductions, are useless, while on the other hand deductions alone from a supposed unchangeable law, would soon become obsolete, by reason of its limitations, which are eventually revealed by new discoveries. If we possessed a universal law, deductions therefrom would be without limit, and discoveries which are now made by accident, would appear as a process of evolution. This is the case with pure mathematics in which there are no discoveries, for each new fact is the result of a process of deduction or evolution.

The principle of mathematics, however, as it is generally understood, is not a universal law, and although it is universally applied in all scientific work, it must be remembered that there are other factors that enter into all problems, each of which involves separate and distinct principles, producing in the end an anomalous condition, for where more than one principle is involved, there must necessarily cease to be a principle. In pure science, as for instance pure mathematics, there is but one principle involved, and its application to symbols that have no in-

trinsic value involves no complex condition, but in the concrete sciences, we have, besides the mathematical factor, other factors, principally physical, chemical, mechanical, and economical, to say nothing of the temperamental known as the "personal equation," all of which render the condition very complex, and the application of an absolute law, unless it be universal, impossible. This is of an absolute law, unless it be universal, impossible. This is particularly the case in connection with our so-called science of chemistry, for the application of its principles involves all of the above extraneous factors, and although they may be reduced to a minimum by the use of delicately adjusted appliances in connection with investigation work, they are always present to interfere with the complete application of the principle.

The question, therefore, "Is chemistry a science?" if we answer it on the basis of the definition of science as "organized common sense," by which we mean a system involving an absolute principle from which we can make absolute deduction, must be answered in the negative, for as we have seen, our deductions at best are only approximate, and in the most important branch of chemical work, industrial chemistry, its application is more or less a total failure. While it may be true that chemistry acquired the distinction of being called a science after the acceptance of Dalton's atomic theory as a working basis, it cannot be claimed that the enormous advance since made in the field of chemistry is due to the application of this theory, since in practical work we do not actually apply it at all. Advancement is due rather to the inspiration that this theory affords, by establishing a definite goal towards which concerted action may be directed, for it is concerted action and unity of purpose among workers along any particular line, that produces results.

That chemistry is not a pure science, does not, however, imply that it is to be deposed from its position of importance among other so-called sciences, for the same condition applies to them all, with the result that we have no real science except pure mathematics. Pure mathematics, however, limited as it is to symbols only, would be useless if it had no application to concrete things in connection with the other so-called sciences, and as this application is not perfect, owing to other factors present, we must conclude that there is no such thing as a perfect science defined as "organized common sense."

To escape from this apparent absurdity, we are compelled to change our definition of the term science, and devise a definition that will apply to existing conditions. Instead of defining science as "organized common sense," we might define it as "practical common sense," or as Prof. James might call it, "pragmatic" common sense, that is to say, the sense that makes use of anything that works. All sense is common sense, and the so-called organized common sense or science is judged, not by the degree of perfection of its system, however necessary perfection may be as a criterion of pure science, but rather, is it judged by practical consideration, by results.

Human nature is practical if it is anything, and a theory, no matter how profound it may be, even if it be a theory of life, has little interest for us if it is not practical. When a new theory is propounded, our first question is not, is the theory true, but, will it work, will it "deliver the goods"; if not, we have no use for it. We judge a theory, or system or any line of work, solely by practical considerations, and these practical considerations are not academic but humanistic, not scholarly attainments, but things that add to the happiness and comfort of mankind.

Human nature looks for immediate returns, and of all lines of work, can there be found one that gives for labor expended more satisfactory returns than that which is included under the name of chemistry. It is ostensibly based on a fundamental principle, and although the results may not accord with the principle, the results are, nevertheless, approximately what we are looking for, which is achievement, and even if incomplete, we are satisfied to call it a science. If its field of operations were confined to purely scientific work, where the only object is the relations between hypothetical atoms, its usefulness would be so limited, that its work would be no more productive of happiness than astronomy, which deals with the far distant planets, or the study of metaphysics, that deals with things transcendental.

In fact the field of operations open to chemistry is unlimited, and there is no important line of practical work, in which mankind is interested, that is not in some way related to chemistry. On the other hand, the field of practical chemistry is not limited to so-called chemical relations, but includes within its applications many conditions that are not strictly speaking chemical at all, but mechanical, physical, geological, biological and even psycho-

logical. From a practical point of view we might say that chemistry is the science of all sciences, for it seems to include them all in one great whole. From determining the elements of the stars, down to analyzing our foods; from steel making to farming, chemistry is an important factor, without the assistance of which no industry can hope to succeed. Consequently its problems, which we started out to discuss, are of a most varied character, and their solution requires not only a knowledge of chemistry, but a thorough knowledge of all the other concrete sciences combined, and most of all an appreciation of the fact that success is counted not by the profoundness of a theory, but by practical attainments. Chemistry as a science, is as simple in its operations as the multiplication table, and involves no greater problems because its application is confined to symbols, that give rise to no counteracting conditions. Real problems arise when application is made to concrete things, that involve not only chemical conditions, but physical, mechanical, economical, temperamental, etc. Temperature, concentration, and so-called "mass action," form, size and construction of implements and utensils employed are all factors that must be harmonized and systematized, and this harmonizing process is what constitutes the problems of chemistry, problems that no scientific mind alone, much less, a purely chemical mind can solve. They are solved only by the broad, common sense, "pragmatic" mind, that is fortified with a knowledge of things in general, and often by the mind that boasts of no knowledge whatever, for as is sometimes the case, problems are solved by an ignorant mind, because unhampered and unprejudiced by preconceived laws, whose supposed fixedness often interferes with freedom of thought.

Just where to draw the line that distinguishes a chemist from another worker, is a difficult, if not impossible task, for if we define a chemist, as one who is engaged in solving problems in the field covered by chemistry, an industrial plant, for instance, then we must include every individual connected with the plant, from the officers down to the common laborer, for each, in his own sphere, is engaged in working out some problem connected with the industry. Consequently, a chemist, an industrial chemist in particular, and all chemists are supposed to be industrial in some capacity, is one whose occupation is that of solving problems arising primarily out of the chemical changes that are

constantly taking place in the material universe, but which ultimately embrace every condition that contributes to the material happiness and comfort of mankind. In fact his occupation is philosophical rather than scientific, for instead of looking at things from a scientific point of view, that is from a fixed and limited principle, he learns to look at them from all points of view, which is the philosophical view.

It has been said that "to gain an education is to cultivate an attitude of mind," that is to learn not merely to look at things, but to learn how to look at them. To merely look at things, is to look at them from one point of view, which results in narrow-mindedness, prejudice and bigotry, while the philosophical view cultivates a broad-minded, altruistic attitude of mind, and is productive of the greatest success and the greatest good to mankind.

This is a point that might well be impressed upon chemical students, lest they become deluded with the idea, gathered from their study of the theory of chemistry, that problems can be solved by the application of fixed principles and unchangeable laws, unconscious of the fact that their solution is in the end accomplished by adjusting and harmonizing conditions that are antagonistic and incompatible with any fixed principle that may be laid down in a text-book. Instructors in the natural sciences are too prone to impress upon their scholars the absoluteness of the laws of nature, without taking the necessary precaution of drawing a distinction between theory and practice, between science as organized common sense, and science as practical common sense. The most successful chemist is the one who combines a well-balanced amount of both the scientific and the practical mind, for the problems that will confront him require for their solution the broadest possible attitude of mind. Even those who have had many years of experience, are sometimes liable to be too scientific and to rely too much upon scientific deductions, as for instance when we have worked out some method to approximate perfection on a small scale and then make an attempt to apply it on a larger scale, only to meet with failure and financial loss, because some unforeseen factor has arisen that interferes with the operation.

THE AIR-BRAKE AS RELATED TO PROGRESS IN LOCOMOTION.

BY

WALTER V. TURNER,

Chief Engineer, Westinghouse Air-brake Co., Pittsburg, Pa.

*(Presented at the meeting of the Mechanical and Engineering Section,
Thursday, November 17, 1910.)*

GENERAL AND HISTORICAL.

EVERY moving body is capable, by virtue of its motion, of doing an amount of work before its motion can be diminished or stopped, which is directly proportional to the weight of the body and to the square of the speed at which it is moving. In the case of a vehicle, means must be provided which will permit this work to be done harmlessly and in a proper and pre-determined manner. Otherwise the element of danger involved increases so rapidly with the weight and speed of the vehicle that locomotion, except in its most primitive stages, is prohibitive. The development of locomotion and consequently of transportation is, therefore, dependent in no small degree upon a like or even superior progress in the art of controlling vehicles in motion.

The laws according to which this art progresses can be determined only by following the successive developments which have been made in train control apparatus. This will be treated briefly in what follows, dealing primarily with the principles upon which such apparatus must operate, the methods, both theoretical and practical, by which these principles have been and are being applied to the problem in hand, and the fundamental conditions of service which fix the requirements that must be satisfied by a reliable and practicable device of this character.

PRIMITIVE VEHICLE BRAKES.—Knowing that the ancients travelled extensively, and that the great empires of history moved large armies over the then-known world, accompanied by trains of baggage wagons and war machines, it is natural

to suppose that the necessity for retarding those vehicles must have been plainly manifested. But as a matter of fact, the first suggestion of this necessity by the use of a practical mechanism designed for the purpose does not appear to have been more than 250 to 300 years ago. The primitive carts and wagons which were used in agricultural work, and in connection with the transportation of baggage and supplies for armies, were of such construction that the natural resistance to rotation of their wheels was quite sufficient to bring them to a stop upon ordinary roads; and in cases of steep grades it was always easy to chain a log or stone (Fig. 1) to the back of the wagon, so that by dragging it over the ground the speed of the vehicle was checked.

Indeed, to find the time when the question of braking first came into prominence, it is necessary to go no further back than the period when highways became sufficiently well made and maintained as to admit of a heavy vehicle being drawn over them at comparatively high speed.

A remarkable adherence to one basic combination of elemental parts, of the same general character and function, is to be observed in even the earliest types of brake apparatus. This extends from the simplest primitive forms through the entire progress of the art until they are found to-day, associated, it is true, with great specialization and complexity of detail, but still having essentially the same fundamental components.

This is natural, because, as the moving vehicle must be controlled by self-contained apparatus, it was first necessary to devise means whereby a source of energy or pressure, located on the vehicle, might be made to generate retarding force, opposed to the motion of the vehicle.

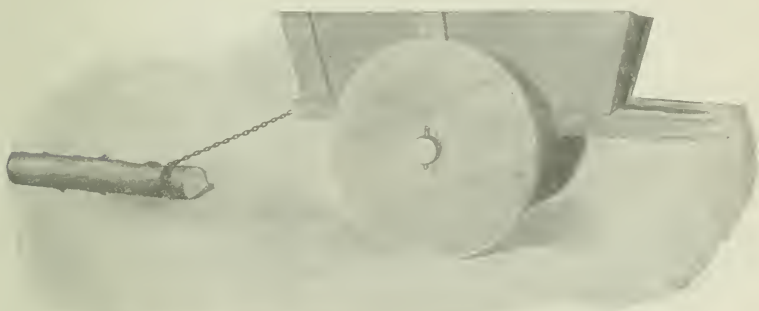
It is easy to see that the revolving wheels and axles offer the convenient and practicable opportunity required, and, consequently, it is not surprising to find that practically all brake devices, no matter how widely diversified in details, have one feature in common. This consists of a block or brake-shoe, as it is called, so located that it may be pressed against the wheel tread with more or less force as may be necessary. This develops a frictional force or pull between the relatively stationary shoe and the revolving wheel which, so long as it does not exceed the "adhesion" of the wheel to the rail or roadway

on which it rolls, tends to retard and finally stop the motion of the wheel and thereby of the vehicle itself.

It can be proved by experiment that the "adhesion" of a wheel to a rail while rolling (static or, more properly, rolling friction) is greater than the frictional force at this point when the wheel is sliding (kinetic friction). Therefore, the maximum retardation on the vehicle as a whole is obtained when the brake-shoe pressure is such as to produce a frictional force at the shoe nearly but not quite sufficient to cause the wheel to slide. This explains why wheel sliding must be avoided for theoretical as well as practical reasons.

EARLY RAILWAY BRAKES.—One of the earliest and simplest

FIG. 1.



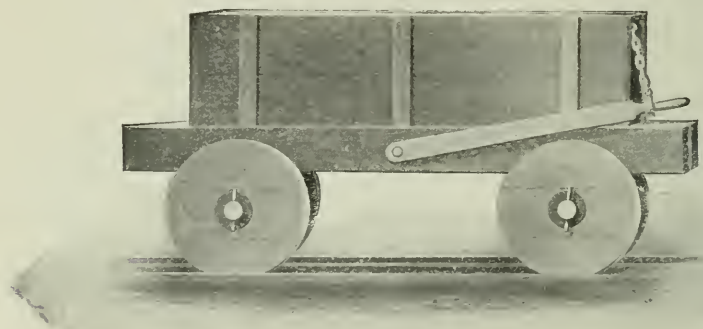
The drag.

means of retarding the wheels of a vehicle in this way was forced by a change in existing conditions, just as the many subsequent changes in methods of locomotion have been responsible for the perfection of the brake as we know it to-day. About the year 1630 an enterprising mine owner at Newcastle-on-Tyne, finding the roads between his mine and the river so bad as to seriously interfere with the hauling of coal, conceived the idea of laying wooden rails in the road and running his cars thereon. The tractive effort of these cars was thereby so much decreased that the necessity of some contrivance to check their speed was at once apparent and brought out simple forms of brakes. One of these forms consisted of a metal-tipped beam which was fast-

ened to the frame of the car in such a way as to scrape along in the ground at the side of the track. Another form was a simple lever pivoted to the side, near the centre of the car, and ordinarily held up by a chain, which, when desired for use, could be liberated and pressed by hand or foot against the top of the wheel, as shown in Fig. 2.

Many other simple devices of like nature were adopted by such rail- or tram-roads as then existed, which require mention only to point out that all made use of a block or shoe forced against the tread of the wheel either directly, or through the medium of some simple combination of rods and levers, whereby

FIG. 2.



Primitive railway wagon brake ; lever on top of wheel, used in New-Castle-on-Tyne, 1630.

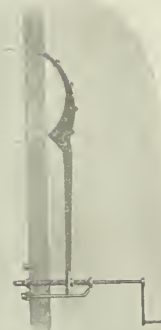
the strength of the man applying the brake might be augmented or multiplied (Fig. 3).

THE STEAM-BRAKE.—As the speeds on these roads were generally quite low and the cars small enough to be drawn by draught animals, such devices served all practical purposes until the inauguration of a new order of things, by the advent of the steam locomotive. With the speeds and weights of cars which then had to be reckoned with it soon became evident that something better than a manually operated brake was needed. In 1833 Stevenson patented his steam-brake (Fig. 4), in which steam pressure, acting on a movable piston, was made to take the place of the hand-operated mechanism by which the force was applied through a system of rods, multiplying

FIG. 3.



RAILWAY TENDER BRAKE - 1830.



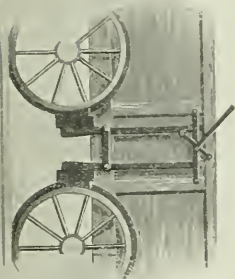
RAILWAY CARRIAGE BRAKE - 1831.



RAILWAY WAGON BRAKE 1831.



TENDER BRAKE - 1831.



RAILWAY WAGON BRAKE 1839.



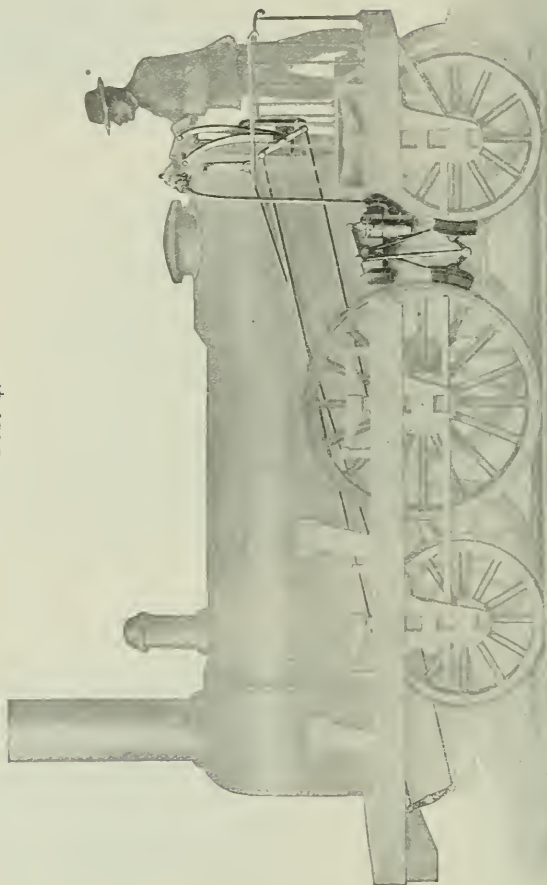
RAILWAY CARRIAGE BRAKE - 1839.

Simple and early types of hand-brakes.

levers (and cams in this case) to the brake-shoe. In this first form of power-brake we have all the elements of a complete power-brake, viz.:

1. Source of power—steam.

FIG. 4.



Stevenson's steam locomotive brake.

2. Means whereby this power may be made to act upon the rods and levers of the brake rigging proper—a "brake"-cylinder with movable piston and rod.

3. Connecting rods and multiplying levers to transmit and

increase the pressure exerted on the brake piston—called the foundation brake-gear.

4. Means for transmitting the force exerted through the foundation brake-gear to the wheels as retarding force or “pull”—this being the function of the brake-shoes as already explained.

In the case of the cars, the hand-operated brake, with various forms of foundation brake-gear, met all practical requirements for some time, though a general realization of the necessity for some form of power-brakes is attested by the fact that during the first 70 years of the Nineteenth Century about 650 patents were granted in England for various kinds of brakes for railroad service.

PNEUMATIC BRAKE.

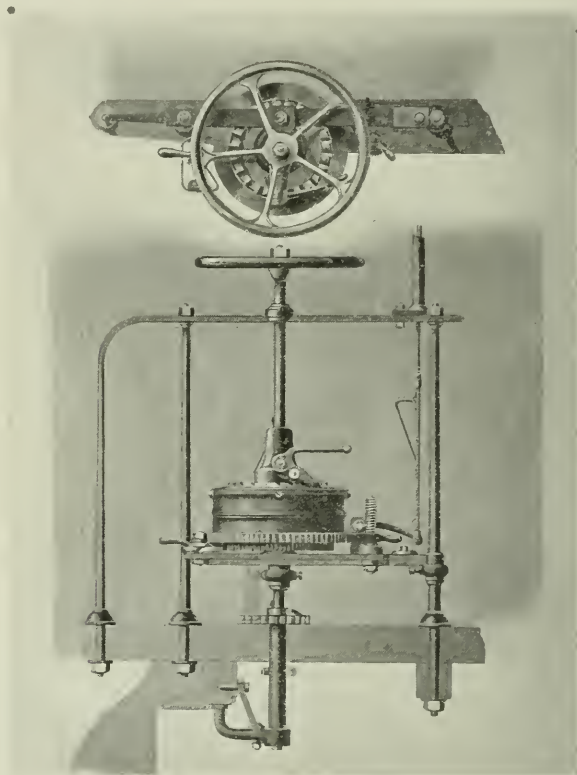
The first pneumatic-brake was a vacuum-brake patented by James Nasmyth and Charles May in 1844. In 1848 Samuel C. Lister patented an air-brake having an axle-driven pump and suitable reservoir to be placed on the “Guard’s Carriage,” and suitable cylinder, pipe, and connections on the various cars to constitute a straight-air equipment much the same as that which followed many years after, except that it was designed to be operated by the guard and not by the engineer.

CONTINUOUS TRAIN-BRAKE.—Of course, the earlier types of hand-brakes underwent considerable improvement, but while the majority of passenger, as well as freight cars, were braked by hand, as more and heavier cars came to be handled in the same train, the necessity for a “continuous” brake or one capable of being put in action on the various cars comprising the train, at the will of the engineer himself, became more and more evident. Some of the various systems originating in this country were extensively tried and seemed to meet the conditions for which they were designed with various degrees of success. The “Creamer” brake (Fig. 5), which was brought into use in 1853, consisted of a large spiral spring attached to the brake-staff, at the end of the car, and which was wound up by the brakeman immediately after leaving a station. Attached to the mechanism was a cord which ran through the train to the engineer’s cab, and the brake was so designed that when the engineer pulled the cord, the coil springs on each vehicle were released and these at once wound up chains

leading to the foundation brake-gear, thereby bringing the brake-shoes against the wheels.

The "Loughridge Chain-Brake" (Fig. 6), which came into use in 1855, consisted of a system of rods and chains continuously connected throughout the train, as follows: On each vehicle were two pairs of small pulleys, each pair sliding toward the

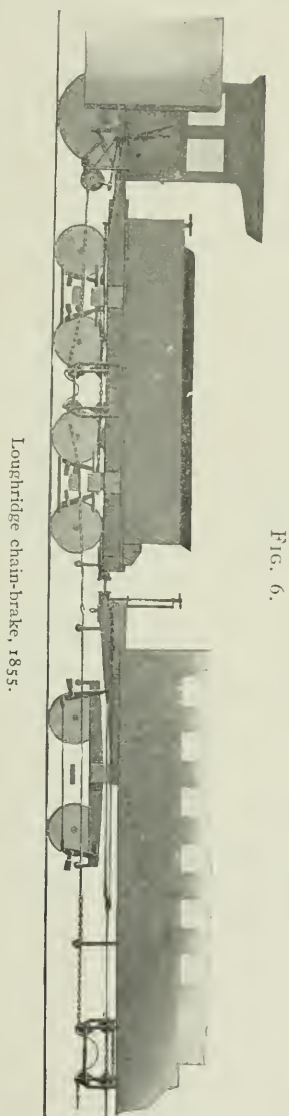
FIG. 5.



Creamer brake, 1853.

other upon an iron framework, but held apart by a spring; to each pair was connected a top rod leading to the foundation brake-gear. Upon the engine was placed a drum connected by a worm and gear to a small friction wheel; when a lever in the engineer's cab was pulled this friction wheel was brought into contact with the periphery of one of the driving-wheels,

thereby causing the drum to wind up the chain and shorten its length throughout the train; in so doing the pulleys upon



Loughridge chain-brake, 1855.

FIG. 6.

each vehicle were brought closer together, thereby applying the brakes.

In addition to the above, various forms of continuous brakes, other than air-brakes, were tried to a greater or less extent from time to time. Among these may be mentioned the Smith Vacuum-Brake, the Westinghouse Vacuum-Brake, the Eames Vacuum-Brake, the Fay Mechanical-Brake, the Clark & Webb Chain-Brake, the Barker Hydraulic-Brake, the American Buffer-Brake, the Widdifield & Button Friction Buffer-Brake, the Rote Buffer-Brake, the Carpenter Electric Air-Brake, and the Card Electric-Brake. From the length of this list it will be seen that to give an adequate description of these various systems would be to occupy with matter of purely historical or curious interest, valuable space and the time of the reader which promise already to be overtaxed by the demands of modern practice and recent development.

While these types of brakes were the result of much ingenuity and skill, and attained to a degree of success sufficient to prove the necessity for, and advantage of a reliable and efficient continuous brake, none of them satisfied enough of the fundamental requirements of a practicable, continuous brake to result in their universal acceptance as a standard in this country.

THE AIR-BRAKE—STRAIGHT AIR TYPE.—The first steps of the complete solution of the problem were taken, and a new line of development opened up, by the genius of Mr. George Westinghouse, who, in 1869 took out his first patents for the Westinghouse Non-Automatic Air-Brake, since generally designated as the "Straight Air-Brake."

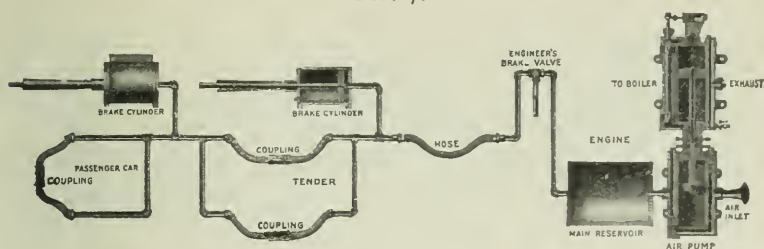
The source of power adopted for this system was the expansive force or pressure of compressed air, obtained from a steam actuated air-pump placed upon the side of the engine, and a reservoir in which the compressed air could be stored. A pipe line from the reservoir was carried throughout the length of the train, connections between vehicles being made by means of flexible hose and couplings. Each vehicle was provided with a cast-iron cylinder, the piston rod of which was connected to the brake-rigging in such a way that when the air was admitted to the cylinder the piston was forced out and the brakes thereby applied. A three-way cock or valve located in the engineer's cab by means of which compressed air could be admitted to the train pipe and thus to the cylinders

on each car to apply the brakes; or the air already in the cylinders and train brake pipe could be discharged to the atmosphere, thus releasing the brakes.

An early form of the Straight Air-Brake is shown in Fig. 7. The air-pump is one of the first forms to come into general use, the so-called "trigger" or "jigger" valve motion and octagonal piston rod being features of particular interest.

This type of apparatus has many good qualities and a very large degree of flexibility, that is, the increase or decrease of the pressure or braking power, so-called, was under the control of the operator to a very marked degree, but had shortcomings which made it unsuitable for use on trains of any considerable length on account of the time required to apply and release the brake and the unequal braking effort throughout

FIG. 7.



the train. More important still, the factor of safety was low; as no warning was given in the event of the hose coming uncoupled, and a parted train meant no brakes. Thus it is seen that it lacked the first essential of an efficient brake, which is, that it must be its own "tell-tale." That is, if an accident occurs to the system, it must result in a brake application instead of a loss of the brake.

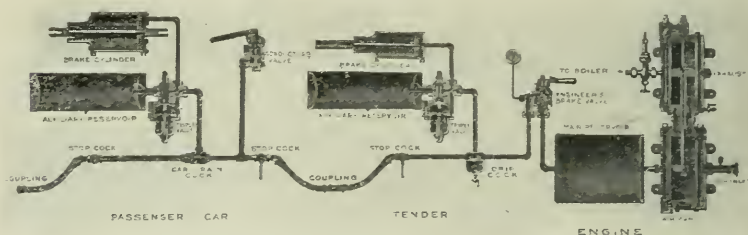
PLAIN AUTOMATIC AIR-BRAKE.

In the natural process and development of railroads, the requirements became more exacting and it was evident that the straight air-brake was not only unsuitable for the reasons just mentioned, but that it lacked essential features. It became more than ever important that the brake must apply automatically.

in case of the train parting. This was so fundamentally necessary that even if the flexibility of the straight air-brake had not already been lost to a large extent by the lengthening of the trains, it would have had to be abandoned because of the infinitely greater safety inherent in a brake of the automatic type. Therefore, the straight air-brake, having served its purpose as an advance agent of something better, gave way to the automatic-brake, which afterwards came to be called the "plain automatic-brake," to distinguish it from a later type that locally reduced the brake pipe pressure, thus producing what is called "quick action."

The first form of this brake, probably the greatest advance ever made in the art, was invented and introduced by Mr. George Westinghouse in 1872 (Fig. 8).

FIG. 8.



The "Westinghouse" plain automatic air-brake, 1872.

The automatic feature resulted from the obtaining of an indirect application of the brakes through the medium of a valve device called a triple valve, and an auxiliary storage reservoir, which were added to the brake cylinder on each car. All of the triple valves were connected together by a continuous pipe, called the brake-pipe, with flexible connections between the cars; this pipe being charged with air whenever the brakes were in operative condition. By this means, the auxiliary reservoir was charged with compressed air for braking purposes on the vehicle to which it was attached; therefore, it was no longer necessary to transmit the air from the locomotive to the vehicle when an application of the brakes was desired. The triple valve is the essential mechanical element in such a system, possessing the three functions of charging the auxiliary reservoir and of apply-

ing and releasing the brakes in accordance with variations in the air pressure carried in the brake pipe; the medium for producing such operations as desired, being, for all general operations, a manually operated brake valve on the locomotive.

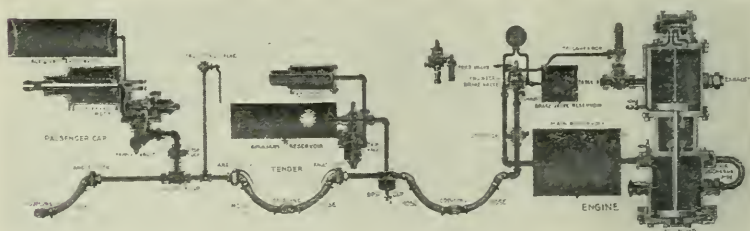
By means of this valve the engineer could apply the brakes either to a part of their capacity, and by steps or graduations, or fully, by a continuous decrease of the brake pipe pressure, but he had no control of the release of the brakes (as with the straight air). The automatic brake releasing locally on each car, while the release of the straight air-brake was controlled on the engine. Therefore, one of the elements of flexibility possessed by the straight air-brake was lost, but, as has been said, this feature had already been very much reduced in value by the lengthening of the train.

Thus, through the instrumentality of the triple valve, the air-brake became automatic, which term applies to that *application* of the brakes which occurs through any material depletion from any cause of brake-pipe pressure, either at the will of the engineer, by hose parting, burst hose, leakage, or at the instance of the train crew, so that this system very materially increased the factor of safety and permitted the use of air-brakes on longer passenger trains, and on the already existing freight trains, in a way that was not possible with the straight air-brake equipment.

QUICK-ACTION AUTOMATIC AIR-BRAKE.—This plain automatic brake was a great improvement in many respects over the straight air-brake, but chiefly from an emergency or safety stand-point, for much of the flexibility (that is, the ability of the operator to increase or decrease the cylinder pressure at will and for any desired number of times in rapid succession) for ordinary service brake operations had to be sacrificed. This brake served the purpose fairly well while trains were short, and speeds, weight and frequency low, but as these factors changed, *its* limitations became more and more apparent, particularly with reference to emergency operation. The application was too slow with long trains, *and for* reasons differing only in degree from those which had affected the straight air-brake. Thus when a quick application was attempted, the shocks were great, nor was the stop as short as required. The reason for this slowness of operation was because the air in the

brake pipe could not be quickly and uniformly reduced throughout its whole length; this, because of increased volume, frictional resistance, and the necessity of its travelling to the one outlet, which was through the brake valve at one end of the train. This limitation was overcome by the invention (in 1887) of the "quick action" triple valve and the equipment with which it was used came to be known therefore as the Quick-Action Automatic-Brake (Fig. 9). The "quick-action" triple valve was identical with the plain triple valve as far as service operations were concerned, but differed from it in emergency in that it automatically vented air from the brake pipe locally on each car. The rapid brake pipe reduction thus resulting is transmitted to the next triple valve and from it serially in the same manner

FIG. 9.



The "Westinghouse" system quick-action automatic-brake, 1887.

to all the valves in the train, thereby reducing the time of full application to about one-sixth of what is inherent with plain triple valves on a 50-car train, and shocks were therefore correspondingly lessened and stops shortened. The reason for this is that the brake pipe reduction with the plain triple valve took place at only one point in the train instead of fifty as with the quick-action valve.

The feature of serial venting of the brake pipe was so important that a second feature of this brake system, which the first mentioned made possible, was, and is to-day, overlooked by many, and perhaps is often not rated at its true value. This feature was the then possible attainment of a different, and higher, braking power for emergency than for service applications. Up to this time the cylinder pressure, or retarding force,

attainable had been the same for both service and emergency applications, but now, since the brake pipe pressure vented could be, and, as a matter of fact, was vented into the brake cylinder with one form of the device, the pressure therein was materially increased whenever quick action took place.

From this it will be seen that to the automatic and graduating features of the brake two others were added, namely, serial quick action and difference or increase in braking power between service and emergency applications. All four of these are now generally recognized (though often not appreciated as they should be) as being fundamentally essential in a brake worthy the name. Moreover, these four features have had and still have great possibilities of extension and development. Attention should be called again to the wonderful adaptability of the original combination of brake cylinder, triple valve, and auxiliary reservoir to the ever-increasing need of more powerful, and what naturally follows, a more flexible brake. *It is truly remarkable that through all subsequent improvements not one of the original functions of the triple valve has been discarded, but that they have been extended and expanded and many new functions added.*

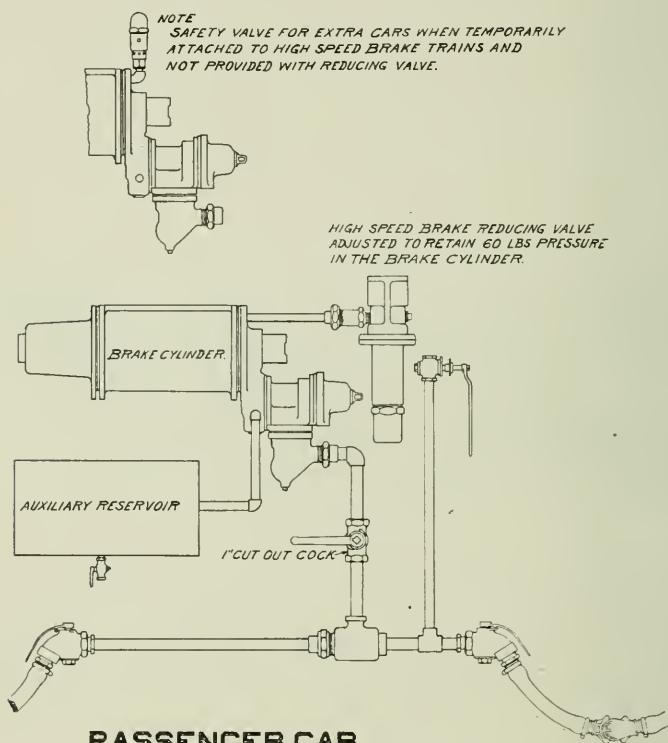
So far, the apparatus employed was the same for both passenger and freight cars, but the still greater frequency of trains, heavier vehicles, and higher speeds made it necessary to provide means whereby a still greater stopping power for passenger service might be available when needed, particularly for emergency applications. This was possible only by increasing the air pressure, since any other method would have made the brake too severe for low speeds; in other words, the percentage of braking power per pound of cylinder pressure was already as great as practical operation would permit.

THE HIGH-SPEED BRAKE.

It was thought, however, that to increase the brake pipe pressure sufficiently to give the desired braking power would result in unpleasant or dangerous shocks, slid and flattened wheels, and other damage from the high brake-cylinder pressure obtainable; therefore, this was not done until the valve known as the "high-speed reducing valve" was perfected in 1804.

The principles utilized by this type of apparatus had been thoroughly demonstrated by the classic Westinghouse-Galton tests in England in 1878. These tests showed that, while the adhesion between the wheel and the rail,—which causes the wheels to persist in their rotation,—is practically uniform at different speeds, the friction between the brake-shoe and the wheel,—which

FIG. 10.



PASSENGER CAR

High-speed passenger brake.

acts as a resistance to the rotation of the wheel, and thereby stops the train,—is considerably less when the wheels are revolving rapidly than when they revolve slowly. It was thus demonstrated that a greater pressure not only could be safely applied to the wheels by the brake-shoes, at high speeds, but also that such considerably greater brake-shoe pressure *must* be applied to the wheels at high speeds, in order to then resist

the motion of the train as effectively as it is resisted with a more moderate brake-shoe pressure at low speeds. This was accomplished by the use of a higher brake pipe air pressure with the standard Quick-Action apparatus, with only the addition of a High-Speed Reducing Valve attached directly to the brake cylinders. This device was designed to limit the brake-cylinder pressure obtainable during a service application of the brakes to what was considered safe and necessary, but when an emergency application of the brakes was made, to permit the brake-cylinder pressure to rise to a considerably higher value than the maximum permitted in a service application, and then to cause a gradual reduction of brake-cylinder pressure, quite slow at first, but becoming more rapid, so as to proportion, as far as possible, with such a device working on a fixed range, the blowdown of brake-cylinder pressure to the reduction in speed as the stopping point is approached. Superior stopping capacity was obtained as already stated, by increasing the brake-pipe air pressure from the generally adopted 70 pounds, as used with the Quick-Action Brake equipment, to 110 pounds, which in emergency applications and with the sizes to brake-cylinder then in use would give about 85 pounds cylinder pressure instead of about 60 pounds, or, in other words, raise the nominal percentage of braking power from 90 to 125 per cent. of the weight of the vehicle.

With this improved equipment when an emergency application was made, full cylinder pressure (85 pounds) was quickly obtained, but was automatically reduced to 60 pounds and held at this point by means of the automatic reducing valve. Thus, if the stop was long enough, the initial nominal percentage of braking power was 125 per cent., while the final was 90 per cent., but the actual retardation of the train kept fairly constant due to the difference in the retarding power of the shoes at high and low speeds already mentioned. Though the coefficient of brake-shoe friction was known to be less at high speeds than at low speeds, it was predicted by many that much wheel sliding would result from raising the nominal power above 100 per cent. of the light weight of the car, but, on the contrary, wheel sliding was lessened and naturally so when the situation is analyzed.

In service applications, the opening from the reducing valve

was larger than in emergency application so that if such a reduction of brake-pipe pressure was made as would cause the brake-cylinder pressure to rise above 60 pounds, the reducing valve would open and vent the air, which otherwise would cause an undesirably high brake-cylinder pressure, to the atmosphere.

This combination, with the quick-action triple valve, is known as the High-Speed Brake, and is illustrated in Fig. 10.

RECENT DEVELOPMENTS IN TRAIN BRAKE APPARATUS.

The typical brake equipments which have been mentioned, namely: straight-air, plain-automatic, quick-action-automatic and the high-speed brake, mark epochs during which the respective equipments were each able to successfully meet the traffic requirements existing for the greater part of the periods during which they were supreme, but as the demands of service became steadily more severe, each in turn gave way to its successor, the improved equipment in each case being in its turn satisfactory for such a time as the conditions which brought it into being were not greatly changed.

This growth, it will be noted, was along lines of improving the degree of efficiency of the fundamental functions of the original plain triple valve, either by increasing the air pressure carried for braking purposes, or by the aid of additions to the valve structure itself, or by the attachment of additional devices to existing apparatus, or by combination of two or more of the expedients just mentioned.

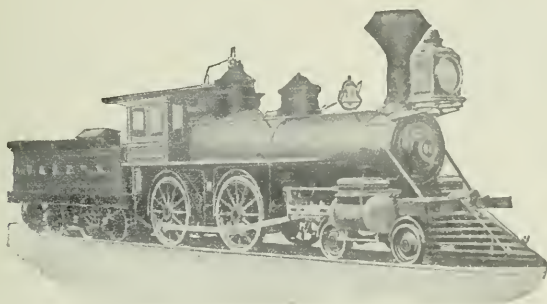
With the high-speed brake, the practical limit to improvement along such lines was believed to have been reached. For some time little or no improvement was thought possible, and this was indeed a fact, so far as further progress along lines previously followed was concerned, for two reasons. (1) About all was then being obtained from the old type of brake that could be gotten from it with the mechanism and arrangement of apparatus then existing. (2) New conditions requiring more specialized apparatus and refinement of the service and emergency features of the brake, as well as of the safety and protective features, began to develop with a rapidity which made it evident that a turning point had been reached.

As a matter of fact, it was rapidly becoming apparent, not

that the air-brake had advanced relatively to the requirements, but that it had not kept pace with the developments of locomotion. In other words, that even the most efficient brake of to-day is, at its best, not able to control and stop a train in the same distance as when the weight and length of the train was less than one-fourth of that to-day. That we have done as well as we have will be appreciated when it is considered that the length of the trains and the volume of air employed have rendered this vastly more difficult, as to service control, and the weight (which involves many factors) to the extent that it would require at least twice the distance in which to stop if the old brake had to be used with present-day conditions.

In addition to the increased weight and speed of trains,

FIG. 11.



American type of locomotive, 1879.

there were, of course, increased number of parallel tracks and frequency of trains. These always bring with them braking problems quite as difficult of solution, and as necessary to be solved, as those which proceeded them, particularly as the tendency is to neutralize or lower the value of many of the factors involved in producing and realizing retarding forces.

It is difficult for one who has not given the subject careful thought to realize the great changes in railroad equipment and operative requirements which have taken place since the introduction of the air-brake, but it is only necessary to review briefly these past and present conditions in order to appreciate the necessity for a similar development and improvement of the apparatus used for controlling trains under these new conditions.

The following comparative tabulations comparing the conditions existing from 15 to 20 years ago and those of to-day with regard to extent of territory covered, capital involved, traffic handled, and so on, will perhaps illustrate the conditions that now have to be faced better than the mere statements which have just been made.

RAILROAD DEVELOPMENT FROM 1889 TO 1909.

	1889	1909	Increase, per cent.
Miles of line	153,385	234,182	52.7
Miles of track	195,958	340,000	73.5
Net capital, etc.	\$7,366,745,000	\$13,508,711,000	63.3
Passengers carried	472,171,000	880,764,000	86.5
Tons freight carried	539,639,000	1,486,000,000	175.3
Locomotives, number	29,036	57,220	197.0
Freight cars, number	829,885	2,113,450	154.6
Employees, number	704,743	1,524,000	116.2
Employees, compensation ..	\$389,785,564	\$1,003,270,000	157.4
Electric railways		50,000	

Locomotives.—The weight on drivers has increased since the air-brake was invented, from 25,000 pounds to 400,000 pounds.

The drawbar pull of locomotive has increased, since the air-brake was invented, from 10,000 pounds to 100,000 pounds.

The total weight of locomotives at the present time is as high as 700,000 pounds.

Working steam-pressure has increased, since the air-brake was invented, from 125 pounds to 225 pounds.

Passenger Cars.—Weights have increased from 20,000 pounds to 150,000 pounds.

Freight Cars.—Light weight of car has increased from 12,000 pounds to 50,000 pounds.

Capacity has increased in the last twenty years from 40,000 pounds to 150,000 pounds.

Passenger Trains.—Schedule speeds have increased from 30 miles per hour to 65 miles per hour.

The energy contained in a five-car train of cars having an average light weight of 30,000 pounds per car, running at a speed of 35 miles per hour, is 6,200,000 foot-pounds; of cars having average weight of 127,000 pounds, running at 65 miles

per hour is 90,000,000 foot-pounds, or nearly fifteen times as much.

Freight Trains.—Train length has increased from 15 to 130 cars; total weight has increased from 300 to 4500 tons and in certain places in the country as high as 6000 tons.

To take an actual example illustrating what is involved in the handling of a modern high-speed passenger train, the following figures are taken from the official report of the Emergency Brake Tests carried on about a year ago by the Lake Shore & Michigan Southern Railway near Toledo:

LAKE SHORE EMERGENCY BRAKE TEST.

Types of vehicles used	Weights	
	Pounds	Tons
Locomotive—Pacific type.....	388,000	194.0
Buffet car.....	149,000	74.5
Dining car.....	140,000	70.0
Sleeping car average.....	125,000	62.5

ENERGY IN TEST TRAINS.

	2 Loco.—10 Cars	1 Loco.—6 Cars
Make up of train.....		
Train weight—pounds.....	2,068,000	1,180,000
Train weight—tons.....	1,034	590
Energy at 40 M. P. H., foot-pounds...	116,816,000	66,595,200
Energy at 40 M. P. H., foot-tons.....	58,408	33,298
Energy at 60 M. P. H., foot-pounds...	262,836,000	149,839,200
Energy at 60 M. P. H., foot-tons.....	131,418	74,920
Energy at 80 M. P. H., foot-pounds...	467,264,000	266,380,800
Energy at 80 M. P. H., foot-tons.....	233,632	133,190

KINETIC ENERGY* IN TRAIN OF 2 LOCOMOTIVES, 10 CARS OF 75 TONS WEIGHT EACH—TOTAL TRAIN WEIGHT, 2,276,000 LBS. OR 1138 TONS.

	40 M. P. H.	60 M. P. H.	80 M. P. H.
Speed.....			
Foot-pounds.....	127,811,200	287,575,200	511,244,800
Foot-tons.....	63,906	143,787	255,622

*Kinetic energy in train of 2 locomotives, 10 cars of 75 tons weight each—at speed of 80 M. P. H. is sufficient to raise 1 ton to a height of over 48 miles.

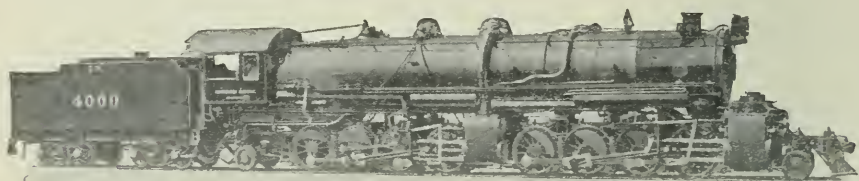
Figs. 11 and 12 present a tangible evidence illustrative of both extremes of the locomotive development indicated in the

tabulations just given. The view of the American type of locomotive (Fig. 11), representing standard practice of 1879 can, no doubt, be recalled by many of you, and is in marked contrast with the enormous Mallet Compound Locomotives (Fig. 12) now being introduced for heavy grade service in various parts of the country.

Similarly the progress in passenger car construction is graphically illustrated by comparing the typical passenger car of 1872 (Fig. 13), with the modern all-steel Pullman cars (Fig. 14), which are being built at the present day.

All the figures which have been given report the maximum conditions of past and present-day practice. As the application of the air-brake has made this enormous increase in weight of vehicles, speeds and length of trains possible, it is fair to assume

FIG. 12.



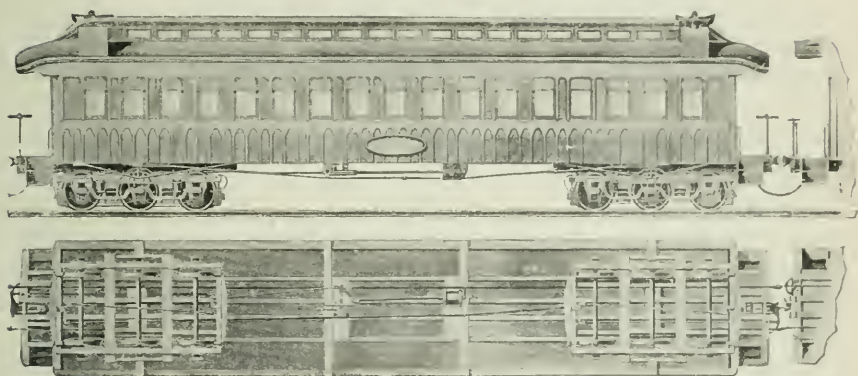
Mallet articulated locomotive—Atchison, Topeka & Santa Fe Ry., 1909.

that the stopping power of the brake should logically be increased in the same proportion so that the stop should be no longer now than formerly.

A concrete example will show forcibly just what this increase in weight and speed means to the operating department if it is to accomplish such an admittedly desirable and necessary result. Under the former conditions the factor of safety in train handling was none too large and it is therefore imperative that we should be able to control modern trains under present existing conditions at least as safely and efficiently as formerly. To do this for five 150,000 pound coaches, running at 65 miles per hour, it is necessary to provide means for controlling over 105,000,000 foot-pounds of energy as compared with about 6,000,000 foot-pounds which was all that the brake

of the early 70's was called upon to control with a train of five 30,000 pounds cars running at 35 miles per hour. When the locomotive used with each train is considered, the total

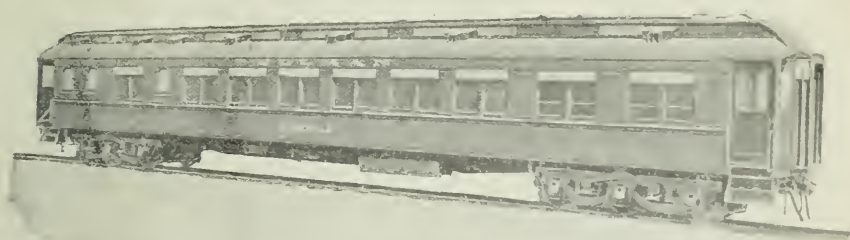
FIG. 13.



P. R. R. passenger car, 1872.

energy in the modern train becomes 162,000,000 foot-pounds, as compare with 9,800,000 foot-pounds, for the train of 1870. It is not surprising, therefore, that the air-brake art demands thoughtful consideration from trained and experienced minds if

FIG. 14.



All-steel sleeping car, 1909.

the railroad traffic of to-day is to be handled with a safety and efficiency even equal to that of the days when the total energy to be reckoned with was one-sixteenth as great. Here again is found another close resemblance between the conditions of ac-

celeration and deceleration, for while it is not especially difficult to increase the speed of a train from 30 miles per hour to 40 miles per hour, it requires the expenditure of a vastly greater amount of energy to increase its speed from 60 miles per hour to 70 miles per hour. In like manner, for any given increase in speed the additional amount of work required from the brake increases in geometrical, not arithmetical, ratio. If, therefore, the improvements for the heavier trains and higher speeds of to-day permit of stopping in about the same distance as could be done with the brake of forty years ago and the trains of that period, we should congratulate ourselves for having held our own.

The mere power necessary to accomplish this is indicated by the fact that the total maximum force exerted by the push rod of the 6-inch brake cylinder of the early equipment was 1700 pounds, while with the 18-inch brake cylinder used on the heaviest coaches, a maximum pressure on the push rod of 26,670 pounds is obtainable.

From the above it will be apparent that many features must now be considered which did not exist when the brake was first invented, particularly on the physical side of the problem. For example, the amount of work required per square inch of brake-shoe surface is vastly greater. This is a condition seldom noticed and yet of great significance, as the following comparison will show :

In the report of one of the earliest brake trials in the history of continuous brakes, made on the Midland Railway, near Newark, England, in 1875, and since known as the Newark trials (see *London Engineering*, June and July, 1875), the best brake performance recorded was by a train of fifteen, 21,000 pound (average), four-wheel carriages, fitted with a primitive form of the Westinghouse Automatic-Brake, one cast-iron brake-shoe being used on each wheel. The best stop was made from a speed of 52 miles per hour, the highest that could be obtained, in 18 seconds. This corresponds to the performance of 15.5 foot-tons (1 ton = 2000 pounds) of work per brake-shoe per second. In the classic Westinghouse-Galton Tests, which followed about three years later, the four-wheel experimental van used weighed 18,200 pounds, and was fitted with two brake-shoes per wheel, and from 52 miles per hour speed a

stop was made by the experimental van alone in $11\frac{1}{2}$ seconds. Here the work done was only about 9 foot-tons per brake-shoe per second.

In 1875 the standard passenger coach used on the Pennsylvania Railroad weighed 39,300 pounds and had four-wheel trucks. To stop such a car from 52 miles per hour in 18 seconds required only 12.33 foot-tons of work per brake-shoe per second, or less than that required of the brake on the Midland train, although the Pennsylvania car weighed 18,300 pounds more. This is, of course, due to the fact that eight brake-shoes were available to do the work as compared with four on the Midland train. Contrast with the above a modern Pullman car weighing 160,000 pounds and having six-wheel trucks. Assuming that from a speed of 52 miles per hour that stop could be made in 18 seconds, the work done would be 33.5 foot-tons per brake-shoe per second, or over twice that of the Midland train, notwithstanding that there are twelve brake-shoes to do the work instead of four. But modern express train speed may be expected to run frequently as high as 75 miles per hour, and to make a stop from this speed in, say, 35 seconds (which would be about the best that could be expected of the modern brake equipment) would require 35.8 foot-tons per brake-shoe per second, or not much more than when a stop of 52 miles per hour is made in 18 seconds. But to have the same absolute safety under modern conditions as existed in 1875 would require the stop to be made in at least the same distance and time, and to stop a 160,000 pound car from a speed of 75 miles per hour in 18 seconds would require 69.6 foot-tons of work per brake-shoe per second or about $4\frac{1}{2}$ times that in the case of the Midland train. (What this would be with four-wheeled trucks will be appreciated.) Even if two brake-shoes per wheel could be used instead of one there would still be over twice as much work to be performed by each brake-shoe per second if the trains of to-day at the speeds now attained in high speed service are to be relatively as safe as the trains of thirty years ago. Furthermore, the use of two brake-shoes per wheel is rapidly becoming a necessity, not only on account of the great amount of work to be performed by each brake-shoe, but also because the brake-shoe pressure required by modern conditions of high speeds and heavy cars are becoming so great that in emergency

applications a heavier pressure is brought to bear on the axle and journals by the brake-shoe acting on one side of the wheel only than is imposed by the weight of the car resting on that wheel.

The tremendous significance of this increase is but faintly appreciated by those who have not had occasion to investigate this aspect of the question. The cast-iron brake-shoe is to-day practically as it was thirty years ago. This brake-shoe must now do four times the amount of work by frictional resistance to the rotation of the wheel, as formerly. It may be suggested, "Why not quadruple the pressure per brake-shoe?" But it also must be remembered that when the brake-shoe pressure is multiplied by four, the actual retarding force is by no means quadrupled, for three vital adverse factors are being overlooked, viz., the effect of increased pressure, speed, and temperature on the coefficient of friction between the wheel and the shoe. Exactly how great an effect these may have depends, of course, on the conditions of the individual test considered, but that it is considerable is proven by the fact that a stop from a speed of 75 miles per hour in 35 to 40 seconds, instead of 18 seconds, is considered good, although we are to-day using about four and a half times as much pressure per brake-shoe as at the Newark trials.

It should be stated that in the above no account is taken of the rotative energy of the wheels. If this is considered, it is evident that the figure for the modern conditions will be still more in excess of those of the past, on account of the wheels being heavier and there being a greater number per vehicle.

Again, the difference in air pressure required to apply and release the brakes is by no means as easily obtained to-day as when trains were short. The air supply required for short trains with small brake cylinders was obtained with compressors of much less capacity than is now necessary to employ: witness, the 6-inch air compressor of the early days of the brake, with its capacity of not over 15 cubic feet per minute, as compared with the cross compound compressors now used, which have approximately 125 cubic feet capacity. The reason for this is apparent, for it required, not so very long ago, about 25 to 30 cubic feet for a full application; now 300 cubic feet is required.

In general, therefore, it may be stated that the brake which would satisfactorily meet the requirements of past conditions, falls short of the maximum efficiency which it should be possible to attain, in proportion to the increase of the requirements of present-day service over those of the past. The force of this is apparent when the same comparison is made between the locomotives and cars of the two periods. This review of the conditions and what is involved, which is by no means exhaustive, will serve to give an idea of the magnitude of the problem. How the various stages of this problem have been solved, as they presented themselves, will be shown best by a consideration of the features and functions of the improved brake apparatus that was developed to meet the conditions just explained.

CHARACTERISTICS OF IMPROVED BRAKE EQUIPMENTS.

While the fundamental service and emergency features of the Quick-Action Brake could not be departed from on account of the necessity for maintaining interchangeability of apparatus, and operative function, it was clear that in designing a brake to meet these new conditions, not only must the fundamental features of the old brake be improved to their highest possible efficiency, but new features must be added, some of which were inherently impossible if the design were carried on along the lines previously laid down.

With this as a point of departure, the development of the newer forms of locomotive, passenger and freight brakes was commenced and it may be fairly said that with the incorporation of the new features which will be explained in what follows, the air-brake entered upon a new era of its history as distinct from that which preceded, covering the progress of the art from the development of the plain automatic brake to the high-speed brake, as that era was distinct from those of the straight air-brake and of the hand-brake which marked the earlier history of the art.

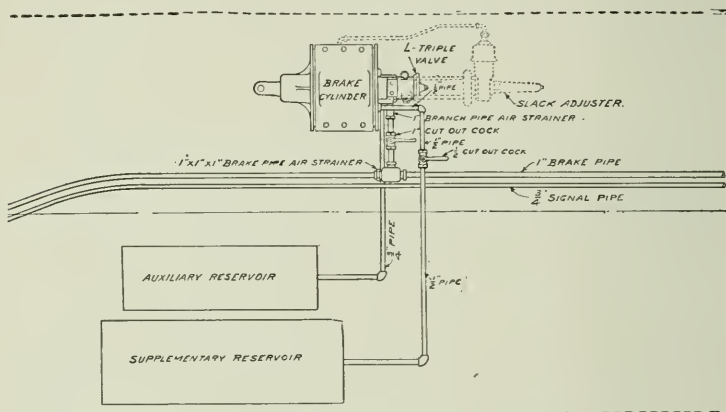
Briefly stated the recognition of the new principles required by the changed conditions referred to, led, in the case of the passenger brake, to the incorporation of the following features

in addition to those characteristic of the previous form of equipment: (See Fig. 15.)

1. Quick rise of brake-cylinder pressure so that the braking power may reach its maximum in the shortest possible time and thus begin to be effective in reducing the speed when at its highest value—and when the increase in distance run before coming to a stop is greatest for every second's delay.

2. Uniform braking power on all cars, irrespective of size of equipment and variation in piston travel, thus contributing largely to the convenience and comfort of passengers, as well

FIG. 15.



Improved passenger brake equipment, type "LN."

as making the brake more reliable and therefore easier to manipulate.

3. Maintenance of both service and emergency-brake cylinder pressures up to the capacity of the ample storage reservoirs of the cars. This is of the greatest advantage in overcoming the ever present and often serious depletion of brake-cylinder pressure by packing-leather leakage.

4. Predetermined and fixed limiting of maximum service braking power, without a safety valve or other blow-off device. This maintains the proper margin between the power of service and emergency applications and tends to reduce wheel sliding without wasting air and with a minimum of apparatus thus resulting in economy both of operation and maintenance.

5. Quick service feature to compensate for increased length of train and bring about more prompt, uniform and certain application of brakes.

6. Quick recharge of the auxiliary reservoirs to offset longer trains and larger cylinders and reservoirs and insure a prompt application of the brakes when desired and prevent the depletion of the auxiliary reservoir pressure.

7. Graduated release feature to add to the flexibility of the brake by making it possible to graduate the brakes off as well as on and so to handle the train more smoothly, with a greater saving of time, and a reduction in the amount of wheel sliding.

8. Much higher brake-cylinder pressure obtained in emergency for the same brake-pipe pressure carried, which pressure is maintained and retained during the complete stop, thus materially shortening the stops and adding greatly to the safety of the trains.

9. Automatic emergency application on depletion of brake-pipe pressure. This is a safety and protective feature of great value, in that it insures sufficient braking power being automatically obtained to bring the train to a stop in case the system is depleted below a predetermined pressure either by careless manipulation or accidentally.

10. Full emergency braking power at any time, thus placing the maximum stopping power the brake has to offer at all times ready for use by the engineer whenever an emergency arises, irrespective of what may have preceded.

11. Separation of service and emergency features so that the necessary flexibility for service applications can be obtained without impairing in the slightest the emergency features of the equipment and conversely, so that undesired quick action is practically impossible.

12. High maximum braking power secured with low total leverage, with correspondingly greater over-all efficiency of the brake.

13. Better mechanical design resulting in more uniform wear of parts and ease of access for removal or repairs.

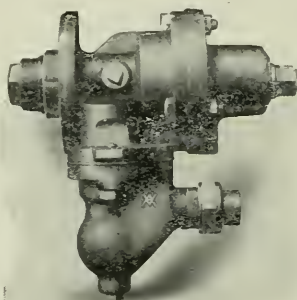
In the case of the freight brake, the change in the conditions which require a change in apparatus were in the direction of greatly increased length of trains, and difference between the

light and loaded weights of the cars. The features of the new freight brake were therefore developed with particular reference to those considerations as follows: (See Fig. 16.)

1. Ability to apply and release the brakes without fear of shocks, under conditions where they are certain with the old brake, gives an added value to all rolling stock.

2. As only a comparatively light reduction is required with the quick service valves to apply all the brakes and with uniform cylinder pressure, there is not sufficient braking power developed in any one part of the train to cause the slack to run in or out severely. On the other hand, with the old brake, a heavy reduction is required to apply the brake at the rear of a long

FIG. 16.



Type "K" freight triple valve.

train, the effect of which is to bunch the slack severely with consequent running out again as the brakes take hold at the rear and the draft springs recoil. As shock is the complement of time and the place where the retarding force is developed, it will be seen that shocks, due to brake applications, will be greatly reduced with the new valve, for while the time required to dissipate the energy of the moving train will be the same, the distribution of the braking power will be different, as it will be divided among all the vehicles in the train instead of first one end and then at the other.

3. Because more applications and release can be made in the same time with the new brake than with the old—much better control and safer operation of the long trains are obtained.

4. On account of the uniform release feature, and because a maximum or full service application of the brake is seldom required with the new brake, the release is more prompt and certain at the rear (which, as has been shown, is the vital place of a long train), and the number of "stuck brakes," flat wheels, and shocks are greatly reduced, particularly as no damage can be caused by the engineer opening the throttle before the brakes at the rear have released.

5. The uniform recharge feature assists in this, inasmuch as the number of "stuck brakes" (resulting from a re-application due to over-charging after a release) is reduced and more equal response of all the brakes secured for subsequent application.

6. The quick service feature makes possible much shorter stops, which is important at all times, but particularly where block signals are in use. This makes unnecessary quick action applications of the brake except in cases of actual danger.

7. The uniform release feature in grade work to a large degree acts as an automatic retaining valve, which is one of the factors in the increased control.

8. The uniformity of application and release tends to reduce the serious effects of the wide difference of braking power with loaded and empty cars in the same train.

9. That vital factor in train control, the personal equation, is made more uniform; as less skill and judgment is required to get good results, while lack of these cannot result in so much harm.

10. As the air required to obtain the same control is only one-third of that required by the old brake, there is much less danger of the supply being inadequate, and with brakes in a reasonably operative condition, there is more likelihood of the engineer stalling or stopping than of "losing his air."

11. Much shifting of lading and breaking-in-two now caused, independent of the brake, by stopping and starting, will be eliminated, as slow downs instead of stops can be made.

12. More tonnage can be handled, and at higher and more uniform speeds, with safety, than has heretofore been possible.

13. Accidents, due to broken wheels, will be fewer, as with the new valve each brake does nearer its share of the work; thus, the excessive heating, due to hand brakes being used, or a few brakes doing the work, no longer takes place.

14. (a) The old valves are greatly helped by the new ones when mixed in a train. (b) The new features are simply additions to the old valves, the fundamental operative functions and principles remaining the same as in previous forms.

15. With the empty and load brake, greatly increased tonnage can be handled, with equal or even more safety and for mixed empties and loads in the same train the elimination of damaging stresses due to inequality of braking power on empty and loaded cars. The characteristics of this equipment and its peculiar advantages merit a more extended description which will follow a little further on.

In the case of the locomotive brake, the new features characteristic of the improved equipment were naturally in part due to the necessity for bringing the locomotive equipment up to an equal efficiency with the improved passenger and freight brake apparatus as just outlined.

In addition, however, certain desirable operative features had long been recognized, but remained impracticable until the establishment of a new basis for design afforded an opportunity for including in a compact and mechanically satisfactory combination of parts, all that previous experience had shown to be desirable in an efficient locomotive brake (see Fig. 17). Briefly stated these are as follows:

1. Either entirely independent or simultaneous operation of the train and locomotive brakes as may be desired, thus permitting of much greater degree of convenience and flexibility in handling long trains, especially on grades, in switching, etc.

2. Maintenance of brake-cylinder pressure whether partial or full application, up to the capacity of the compressor, thus insuring that the desired amount of braking power on the engine will be obtained and maintained irrespective of the leakage which is so difficult to prevent in the case of locomotive brake cylinders especially.

3. Uniform brake-cylinder pressure in all brake cylinders on the locomotive, irrespective of piston travel, number of cylinders or leakage, thus doing away with the necessity for different size or type of operating mechanism for different sizes of cylinders or types of locomotives as well as insuring against variations in braking power due to differences in piston

travel, which must always be reckoned with on account of the brake-shoe wear or neglect in adjustment.

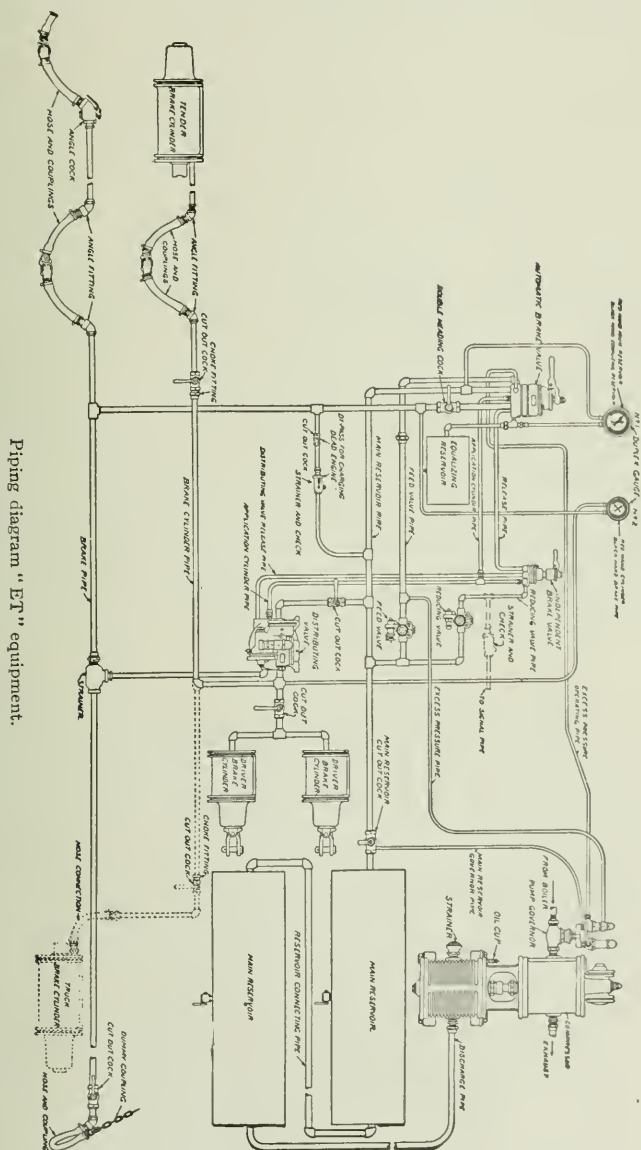


FIG. 17.

4. Predetermined and desirable increase in emergency brake-cylinder pressure over the maximum obtainable in service, thus

securing for the locomotive brake equipment an advantage long recognized as fundamental for all car-brake equipments.

5. Automatic protection against loss of air required for braking due to brake-valve handle being left in lap position by mistake.

6. Graduated release feature for the locomotive brakes which will then work in harmony with the new graduated release type of passenger car brake.

That the above features are all in the direction of increased convenience, economy and safety in the handling of both passenger and freight traffic, is self-evident, but when it is further considered that these advantageous improvements have been incorporated in a combination of apparatus less complicated and with fewer number of parts than required by the old equipment at its best and that the mechanical design and arrangement of parts has been greatly improved with respect to minimizing the wear due to ordinary service and in increased ease of maintenance and repairs, it will be seen that the character and degree of the improvements which have been made are in accord with, and not antagonistic to, the demands of modern railroad service for apparatus of the highest efficiency coupled with a maximum of economy and a minimum of complexity.

(To be continued.)

The Influence of Heat-treatment on the Hardness of Bronze.
E. HEYN AND O. BAUER. (*Mitt. Kgl. Material prüfungsamt.*, xxviii. 344.)—This shows the value of micrographic investigations in solving practical metallurgical problems. Some new bronze bushes had "smeared" the shafts running in them, and it was desired to find the reason. Chemical analysis showed that they had the same composition as others which had behaved satisfactorily, viz., 93 per cent. of copper and 7 per cent. of tin. Hardness tests proved that the new bushes were softer than the old and microphotographs revealed quite different structures. The hard samples showed two distinct constituents, one rich in copper, the other rich in tin. The soft samples were composed of crystals of copper-tin alloy. The hard samples had been quickly and the soft samples slowly cooled between two critical temperatures, which for an alloy of this composition are 1030° and 850° C. To confirm this view a sample showing the "hard" structure was slowly heated to 900° C., kept at this temperature for half an hour, and allowed to cool during 1½ hours to 765° C. It was then cooled more quickly. The "hard" structure was completely changed to the "soft" structure.

Electric Incandescent Lamps. G. LEIMBACH. (*Z. wiss. Photogr. etc.*, viii, 333.)—For a number of lamps now on the market, the following data have been determined, viz., the watt consumption, the total radiation by the aid of the bolometer, and the luminous radiation in the same way, after the infra-red rays have been absorbed by a solution of ferrous-ammonium sulphate. The results are shown in the following table where *A* represents the specific consumption of watts per mean candlepower, *B* the relative radiating power, *i.e.*, the energy value of the total radiation divided by the energy consumed, *C* the luminous effect, *i.e.*, the energy value of the luminous radiation divided by that of the total radiation, *D* the efficiency, *i.e.*, the energy value of the luminous radiation divided by the energy consumed, *E* the absolute luminous radiation, *i.e.*, the mean spherical luminous radiation divided by the mean spherical candlepower, and *F* the absolute specific luminous radiation divided by the absolute specific luminous radiation of the Hexer candle.

	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>	<i>F</i>
		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Watts per sq. cm.</i>	
Carbon-filament lamp.....	3.8	61.9	2.85	1.75	531×10^{-9}	0.62
Nernst lamp.....	2.0	49.2	4.43	2.17	340×10^{-9}	0.40
Tantalum lamp.....	2.0	64.8	4.26	2.75	449×10^{-9}	0.52
Osram lamp.....	1.5	75.6	4.63	3.50	418×10^{-9}	0.49
A. E. G. lamp.....	1.7	80.5	4.41	3.55	482×10^{-9}	0.56
Bergmann lamp.....	1.7	68.5	5.03	3.44	473×10^{-9}	0.55
Just Tungsten lamp.....	1.7	72.2	4.44	3.20	437×10^{-9}	0.51
Sirius colloid lamp.....	1.5	65.4	5.42	3.55	436×10^{-9}	0.51

Metallic Radium. P. CURIE AND A. DEBIERNE. (*Comptes rendus*, cli, 523.)—A liquid radium amalgam, unstable in air, was prepared by the electrolysis of a solution of 0.106 Gm. of pure radium chloride, using a mercury cathode and a platinum-radium anode. The amalgam was rapidly dried, transferred to an iron boat, and heated in a quartz tube in an atmosphere of pure hydrogen, at a pressure above the vapor pressure of mercury at the temperature of the iron boat. Most of the mercury distilled over at 270° C. and the temperature was then gradually raised to 700° C., when the whole of the mercury appeared to be expelled and the radium began to volatilize; the radium vapor vigorously attacked the quartz tube. The residuum in the boat was a bright, white metal, melting at 700° C., which adhered strongly to the iron. It is rapidly attacked by air, becoming black, probably owing to the formation of a nitride. It blackens paper and decomposes water, mostly passing into solution; the dark colored residue dissolves almost completely on adding a few drops of hydrochloric acid. The radio-active properties of the metal appear to be normal.

FRANKLIN INSTITUTE

(Proceedings of the Stated Meeting, held Wednesday, November 16, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1910.

The Stated Meeting of the Institute was called to order at eight o'clock this evening by President Walton Clark.

One hundred and sixty-six members and visitors were present.

The minutes of the previous meeting were read and approved.

A communication from The Board of Managers transmitted the minutes of that body and reported the election of two resident and three non-resident members since the last meeting. The communication was received and ordered to be filed.

The President introduced the Lecturer of the evening, Mr. George Atwell Richardson, President of the Intercollegiate Aeronautical Association of America, Member of the Executive Committee of the Aero Club of America. Mr. Richardson's lecture comprised an historical review of the Art of Aviation from the time of the Greek Legend of Daedalus down through the Middle Ages to modern times, and dealt more particularly with the Science of Aeronautics from the beginning through the invention of the balloon by the brothers Montgolfier on through the successive developments of the Art of Aviation to its present state. The lecture was illustrated by numerous lantern slides and by several kinematographs showing balloons and aeroplanes in motion. Following some brief remarks from the Chair the thanks of the Institute were voted to the lecturer and the meeting adjourned.

L. E. LEVY,
Secretary Pro tem.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, November 2, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 2, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2496.—Asbesto-Gleam Shade (Longstreth Medal). Adopted.

No. 2481.—Moore Vacuum Tube Light (Scott Medal). Adopted.

For first reading:

- No. 2426.—Welin's Life-Saving Appliances on Board Ships.
No. 2455.—Hardinge Conical Pebble Mill (Certificate of Merit). Adopted.
No. 2471.—Anderson Draft Regulator (Advisory). Adopted.
No. 2483.—Hand's Cam Milling Machine (Advisory). Adopted.
No. 2490.—Shuman's Degreasing Machine (Advisory). Adopted.
No. 2503.—Bennett Typewriter.

The Special Committee on the award of the Elliott Cresson Medal appointed September 7, 1910, reported upon the attainments and achievements of the several eminent scientists and technologists named below and recommended that the award of the Elliott Cresson Medal be made to these gentlemen for "distinguished leading and directive work" in their respective fields.

The following motions were accordingly made, seconded, and unanimously carried:

Mr. Rogers moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in electrical discovery and in the advancement of electrical application" to Edward Weston, Esq., D.Sc., LL.D., of Newark, N. J.

Dr. Hoadley moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of the physical sciences" to Joseph John Thomson, Knight, D.Sc., LL.D., Cavendish Professor of Experimental Physics, Cambridge University, England.

Mr. Levy moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of electrical theory" to Ernest Rutherford, Esq., Sc.D., LL.D., Professor of Physics, Owens College, Victoria University, Manchester, England.

Dr. Goldsmith moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the field of agricultural and physiological chemistry" to Harvey W. Wiley, Esq., M.D., Ph.D., LL.D., Chief Chemist to the Department of Agriculture, Washington, D. C.

Mr. Levy moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the production and perfection of instruments for astronomical research" to John A. Brashear, Esq., Sc.D., LL.D., of Pittsburg, Pa.

Mr. Christie moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of the iron and steel industries" to John Fritz, Esq., Bethlehem, Pa.

Mr. Clamer moved that the award of the Elliott Cresson Medal be made for "distinguished leading and directive work in the advancement of our knowledge of metallurgical science" to Robert A. Hadfield, Knight, Sc.D., LL.D., of Sheffield, England.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Photography and Microscopy.—Stated meeting held in the Hall of the Institute, October 27, 1910. Dr. Henry Leffmann, President, in the Chair; J. W. Ridpath, Secretary. Sixty members and visitors were present.

The meeting was called to order at eight o'clock. The minutes of the previous meeting were approved as recorded.

Dr. Henry Leffmann presented a communication on "Organic and Inorganic Forms Shown with the Projection Microscope." This very interesting lecture was illustrated by nine microscopic slides of vegetable organic forms including sections of seeds, leaves, roots, etc. Eight slides showing animal forms including mosquito and larva, head of tapeworm, proboscis of moth, etc. Also ten slides of rock sections and other inorganic forms shown by polarized light.

After some general discussion upon the habits and possible extermination of the mosquito from the New Jersey coast, the meeting adjourned at 9 o'clock.

J. W. RIDPATH,
Secretary.

Section of Physics and Chemistry.—The Stated Meeting of the Section was held in the Hall of the Institute on November 3, 1910, at eight o'clock, with Mr. Henry F. Colvin in the Chair.

The minutes of the previous meeting were read and approved.

Mr. J. T. Baker, President of the J. T. Baker Chemical Company of Phillipsburg, N. J., delivered a lecture upon "The Theory of Problems in Chemistry."

He discussed the difficulties which arise when the attempt is made to apply on a commercial scale the results obtained by working on a small scale in the laboratory, and drew the conclusion that the chemist is best fitted to overcome these difficulties "who combines a well-balanced amount of both the scientific and the practical mind." The paper was discussed, a vote of thanks was tendered the speaker, and the paper was referred for publication.

On motion the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, November 10, at eight o'clock. Mr. James M. Dodge, Temporary Chairman. Present: 90 members and visitors.

The minutes of the previous meeting were read and approved.

The Chairman then introduced Dr. D. S. Jacobus, Advisory Engineer of the Babcock & Wilcox Company, who presented an interesting communication on the "Production of Power."

The great developments of the art within the last few years were discussed; comparisons were made of failings and advantages of the different means of generation, and a description was given, with numerous lantern slides, of modern power plants and marine practice.

A lengthy discussion followed the paper in which Messrs Hixon, Stratton, Parker, Gartley, Whittaker, Eglin, Crisfield, and others participated.

A vote of thanks was tendered the speaker and the meeting adjourned.

ALFRED RIGLING,

Acting Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, November 17, at eight o'clock. In the absence of the Chairman the meeting was called to order by Dr. E. Goldsmith.

After the reading of the minutes of the previous meeting the Chairman introduced Mr. W. V. Turner of the Westinghouse Air-Brake Company, of Pittsburg, Penna., who spoke on the subject of Air-brakes.

A detailed account of the origin and early forms of brakes was given and the various steps in the development of the air-brake were fully described.

Numerous lantern slides covering historic features as well as mechanical details were shown during the reading of the paper.

The thanks of the meeting were extended to the speaker and his paper was referred to the Committee on Publications.

Adjourned.

ALFRED RIGLING,

Acting Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. FRANK H. STIFFEL, 723 Chestnut St., Phila.

MR. ALEXANDER P. ROBINSON, Vice-President, Cambria Steel Co., Phila.

NON-RESIDENT.

MR. DONALD McDONALD, President, Gas Company, Louisville, Ky.

MR. WALTER V. TURNER, Chief Engineer, Westinghouse Air-Brake Co., Pittsburg.

MR. JAMES Z. GEORGE, President and Chemical Engineer, The George Company, Memphis, Tenn.

Changes of Address.

MR. HENRY J. CRUMP, 202 W. Logan Square, Phila.

MR. JOHN RAE, 1908 N. Thirty-second St., Phila.

MR. ARTHUR D. EDGERTON, 614 Pettygrove St., Portland, Oregon.

MR. A. McEACHEN Red Springs, N. C.

MR. EDWIN BURHORN, 938 Hudson St., Hoboken, N. J.

MR. WALTER ATLEE, Room 38, Powelton Ave. and Thirty-second St., Phila.

MR. PETER H. MURPHY, 722 Frick Building, Pittsburg, Pa.

MR. E. F. MASON, Inspector Motive Power, P. R. R., Altoona, Pa.

MR. JOSHUA L. BAILY, 32 South Fifteenth St., Phila.

MR. S. W. WHITING, 11 Ware St., Cambridge, Mass.

MR. E. A. MULLER, 501 Mitchell Ave., Avondale, Cincinnati, O.

MR. FERDINAND HAYES, JR., Coleman Building, Louisville, Ky.

MR. GEORGE IRA HERRICK, 933 W. Sixth St., Los Angeles, Cal.

MR. WM. E. ALLEN, 1211 Clover St., Phila.

NECROLOGY.

RESIDENT.

Mr. Israel W. Morris, 225 S. Eighth St., Phila.

Mr. J. Henry Hooven, Norristown, Pa.

Mr. M. Riebenack, S. E. Cor. Powelton Ave. and Thirty-fourth St., Phila.

NON-RESIDENT.

Dr. R. G. Nunn, 5 York St., E., Savannah, Ga.

Mr. John Sutcliffe, Bellevue, Pa.

LIBRARY NOTES.

Purchases.

- SANG, A.—The corrosion of iron and steel.
 DESCH, C. H.—Metallography.
 THOMSEN, T. C.—Internal lubrication of steam engines.
 KINNICUTT, WINSLOW AND PRATT.—Sewage disposal.
 KLEIN AND SOMMERFELD.—Über die theorie des Kreisels. 4 parts.
 TURPAIN, A.—Notions fondamentales sur la telegraphie.
 TURPAIN, A.—Telephonie. Du telephonie Bell.
 D'OCAGNE, M.—Notions elementaires sur la probabilité des erreurs.
 BARBILLION AND FERROUX.—Les compteur electriques.
 REVILLON L.—La metallographie microscopique.
 BAKER, T. T.—The telegraphic transmission of photographs.
 ASHE, S. W.—Electricity experimentally and practically applied.
 SHELDON AND HAUSMANN.—Dynamo electric machinery.
 HALLER AND CUNNINGHAM.—The Tesla high-frequency coil.
 TOCH, M.—The chemistry and technology of mixed paints.
 Taylor Instrument Companies. Weather and weather instruments.
 Engineering News. General Index.

Gifts.

- Institution of Civil Engineers of Ireland. Transactions, volume 36. Dublin, 1910. (From the Institution.)
 New Jersey Geological Survey. Annual report of the State geologist for 1909. Trenton, 1910. (From the Survey.)
 Institution of Naval Architects. Transactions, vol. 52. London, 1910. (From the Institution.)
 Canada Department of Customs. Annual report, No. 31, March, 1910. Ottawa, 1910. (From the Department.)
 Canada Mines Department. Geology of the Haliburton and Bancroft areas, province of Ontario. Ottawa, 1910. (From the Department.)
 Philadelphia Water Bureau. Reports 1905 to 1908. Philadelphia, 1906-1909. (From the Bureau.)
 Baltimore, Md., Water Board. Annual reports, 1906-1909. Baltimore, 1907-1910. (From the Board.)
 Manchester Association of Engineers. Transactions, 1909-1910. Manchester, 1910. (From the Association.)
 Jewish Hospital Association. Forty-fifth annual report. Philadelphia, 1910. (From the Association.)
 Buffalo Bureau of Water. Annual report for 1906 and 1909. Buffalo, 1906 and 1909. (From the Bureau.)
 Canadian Society of Civil Engineers. Transactions vol. 24, pt. 1. Montreal, 1910. (From the Society.)
 Massachusetts Institute of Technology. Register of former students, March, 1909. Boston, 1910. (From the Institute.)
 New Zealand Institute. Transactions vol. 42. Proceedings, 1909, pts. 3 and 4. (From the Institute.)

- Grand Rapids, Mich., Board of Public Works. Annual reports, 1902 to 1910. Grand Rapids. (From the Board.)
- Canadian Mining Institute. Journal, 1907. Montreal. (From the Institute.)
- Canada Mines Department. Bulletin No. 3. Ottawa, 1910. (From the Department.)
- Hocking Valley Railway Company. Eleventh annual report. Columbus, 1910. (From the Company.)
- Nova Scotian Mining Society. Journal vol. 15. Halifax, 1910. (From the Society.)
- Yale University. Treasurer's report, 1909-1910. New Haven, 1910. (From the University.)
- Institution of Mining and Metallurgy. Transactions vol. 19. London, 1910. (From the Institution.)
- Comparative Statistics of Lead, Copper, Spelter, Tin, Aluminium, Nickel, Quicksilver and Silver. Compiled by the Metallgesellschaft, the Metallurgische Gesellschaft, A.G., and the Berg- und Metallbank Aktiengesellschaft. 16th annual issue. Frankfort-on-the-Main, 1910. (From the American Metal Co.)
- Div-a-let. Division by letters. A pastime or mental diversion mostly intended for those who are fond of such things. By W. H. Vail, A.M., M.D., Newark, N. J., 1909. (From Mr. Charles Gilpin, Jr.)
- U. S. Geological Survey. Professional papers No. 68. The ore deposits of New Mexico. By W. Lindgren, L. C. Graton, and C. H. Gordon. Washington, 1910. (From the Survey.)
- Lynn, Mass., Public Water Board. Annual report, 1907 and 1908. Lynn, 1908, 1909. (From the Board.)
- Ontario Agricultural Department. Annual report of the live stock associations of Ontario. Toronto, 1910. (From the Department.)
- Western Australia Mines Department. Report for 1909. Perth, 1910. (From the Department.)
- Fall River, Mass., Annual Reports of the Watuppa Water Board. Fall River, 1910. (From the Board.)
- Canada Department of Trade and Commerce. Annual report, 1910, part 2. Ottawa, 1910. (From the Department.)
- New York State Museum. Bulletin No. 143. Albany, 1910. (From the Museum.)

BOOK NOTICES.

THE TESLA HIGH FREQUENCY COIL, Its Construction and Uses. By George F. Haller and Elmer Tiling Cunningham. Cloth XII + 119 pages, $7\frac{1}{2} \times 5\frac{1}{2}$ inches, 56 illustrations. D. Van Nostrand Company, New York, 1910. Price, \$1.25 net.

Publications for the guidance of amateur mechanics and electricians do not generally undertake to describe apparatus requiring a degree of technical skill beyond the capacity of the average amateur and descriptions of high frequency coils can scarcely be looked for in such works. To assist the increasing number of advanced amateurs the authors present an account of the construction of a 12-inch coil whose details they have worked out by careful experimenting. With the precise descriptions given and the clear illustrations the book should well serve its intended purpose.

DYNAMO ELECTRIC MACHINERY, Its Construction, Design and Operation; DIRECT CURRENT MACHINES. By Samuel Sheldon, A.M., Ph.D., D.Sc., and Erich Hausmann, E.E., M.S. Eighth edition, completely rewritten. Cloth IX + 328 pages, $7\frac{1}{2} \times 5\frac{1}{2}$ inches, 210 figures. D. Van Nostrand Company, New York. Price, \$2.50 net.

The object sought in the preparation of this work has been the production of a text-book for students in engineering. An engineering student has many tasks to perform in the prosecution of his studies and his time is precious. A subject should for that reason be presented with a view to economize his labor in mastering it in the time allotted. That object has been carried out in the present work.

The introductory chapters contain a brief review of fundamental electric and magnetic laws and facts bearing upon the design of electromagnetic machinery. In the chapters which follow each element of dynamo-machines is presented in a direct and lucid manner and with a conciseness that is well adapted to the needs of the modern technical student. With the exception of the introductory chapters the work has been entirely rewritten, bringing it as fully up-to-date as a text-book well can be. A number of industrial applications, such as motor drives and multiple-unit systems of control add materially to its value in stimulating the reader's interest.

PUBLICATIONS RECEIVED.

Annuaire pour l'an 1911, publié par le Bureau des Longitudes. Avec notices scientifiques. Paris, Gauthier-Villars, 1910. Price, in paper, 1 franc 50c.

A Chip of the Old Block or, at the Bottom of the Ladder. By Edwin J. Houston, A.M., Ph.D. 363 pages, illustrations; 12mo. Philadelphia, Grif-fith & Rowland Press, n.d.

The Land of Drought or, Across the Great American Desert. By Edwin J. Houston, A.M., Ph.D. 355 pages, illustrations; 12mo. Philadelphia, Griffith & Rowland Press, n.d.

Sur la structure des scories et "terres cuites" trouvées dans la série pampéenne et quelques éléments de comparaison par Félix F. Outes, secrétaire et directeur des publications du Musée de la Plata avec la collaboration du docteur H. Bücking. [De la Revista del museo de la Plata, tome xvii, pages 78 à 85.] 8 pages, plate, quarto. Buenos Aires, Coni Freres, 1910.

Canada Department of Mines, Bulletin No. 3. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. By Eugene Haanel, Ph.D. 76 pages, illustrations, plates; 8vo. Ottawa, Government Printing Bureau, 1910.

La Misura delle deformazioni dei tubi e recipienti cilindrici sollecitati da pressione interna. Ing. Federigo Giordano. 80 pages, illustrations, quarto. Milano, Ulrico Hoepli, 1910.

Der Kautschuk und seine prüfung von Prof. Dr. F. W. Hinrichsen und Dip. Ing. K. Memmler. 263 pages, illustrations, 8vo. Leipzig, S. Hirzel, 1910.

The applications of Collodion Emulsion to three-colour photography, process work, isochromatic photography, and spectroscopic work. Second (enlarged) edition. By Henry O. Klein. 125 pages, illustrations, 8vo. London, A. W. Penrose & Co., 1910. Price, 5 shillings.

Manila Bureau of Science. The mineral resources of the Philippine Islands with a statement of the production of commercial mineral products during the year 1909, issued by the division of geology and mines, Bureau of Mines, Warren D. Smith, chief. 81 pages, plates, maps, 8vo. Manila, Bureau of Printing, 1910.

Installations of the "Chloride Accumulator" on the System of the Gulfport and Mississippi Coast Traction Co. Bulletin No. 125. 8 pages, illustrations, quarto. Philadelphia, Electric Storage Battery Co.

Canada, Department of Mines. Report of analyses of ores, non-metallic minerals, fuels, etc., made in the chemical laboratories during the years 1906, 1907, 1908. Arranged by F. G. Wait, M.A., F.C.S., Chief Chemist. 126 pages, plates, 8vo. Ottawa, Government Printing Bureau, 1909.



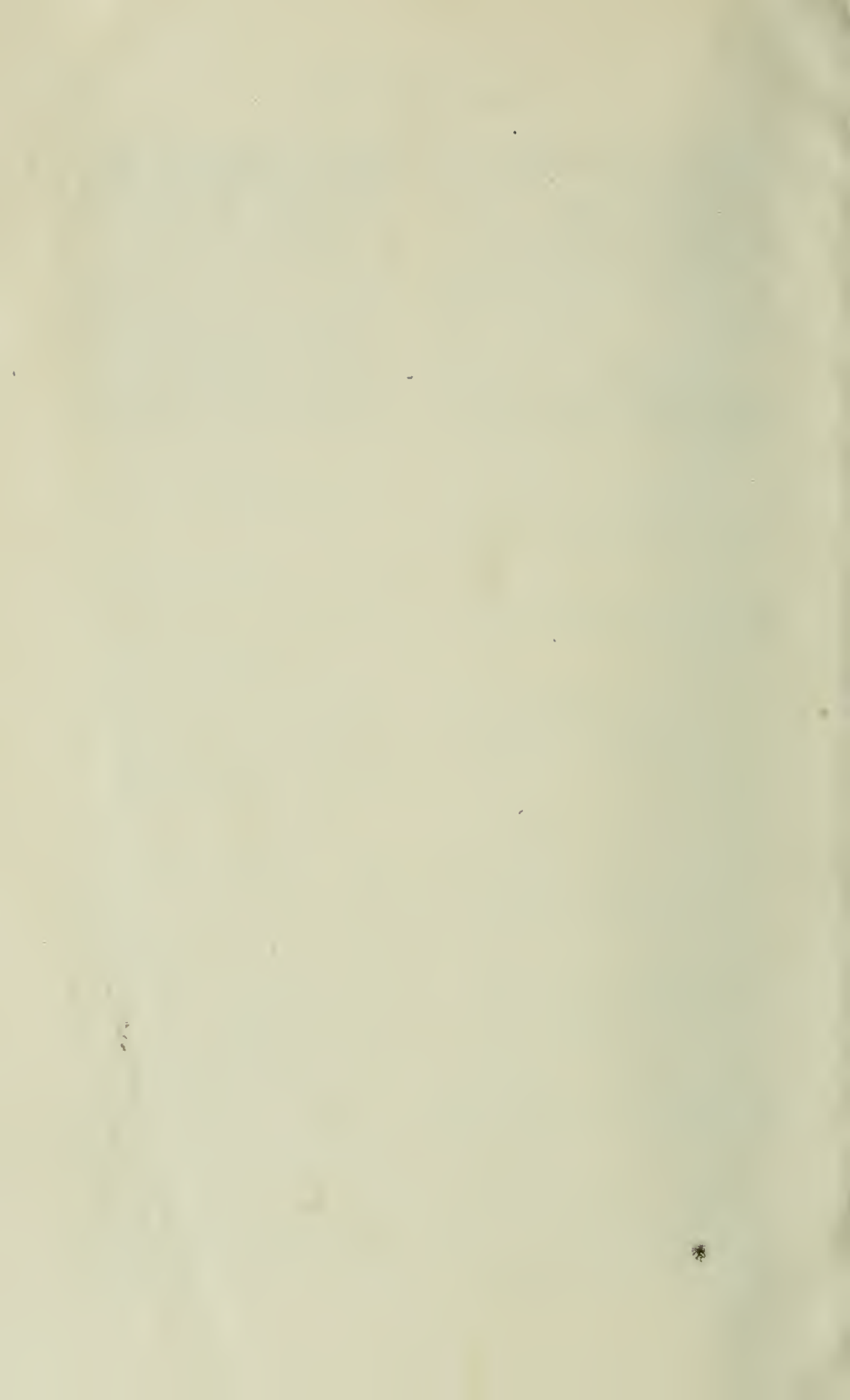
PRESS OF
J. B. LIPPINCOTT COMPANY
PHILADELPHIA

INDEX TO VOL. CLXX.

- Aeroplane motors (Petit), 291
 Aerial propellers and some test results (Larard and Boswall), 303
 Air-brake as related to progress in locomotion (Turner), 461
 American patents in England (Williams), 317
 APPLETON, JOSEPH: Some recent problems in storage battery engineering, 327
 Atomic weights—An historical sketch (Hepburn), 217
 Aviation and aeroplane motors (Petit), 291
- BAKER, J. T.: Problems in chemical industry, 451
 BOOK NOTICES:
 Allen's commercial organic analysis (vol. ii), 323
 Ashe, S. W.: Electricity experimentally and practically applied, 396
 Baker, T. T.: Telegraphic transmission of photographs, 394
 Barbillion, L., and G. Ferroux: Les compteurs electriques, 395
 d'Ocagne, M.: Notions elementaires sur la probabilité des erreurs, 395
 Fry, H. P.: Notes on mechanical drawing, 396
 Haenig, A.: Der Graphit, 66
 Haenig, A.: Der Kronstruktions stahl und seine mikrostruktur, 228
 Haller & Cunningham: The Tesla high-frequency coil, 503
 Penrose's pictorial annual (1909-10), 66
 Révillon, L.: La métallographie microscopique, 396
 Sheldon and Hausmann: Dynamo-electric machinery, 503
 Stillman, T. B.: Engineering chemistry, 323
 Turpain, A.: Notions fondamentales sur la telegraphie, 394
 Turpain, A.: Telephonie, 394
- BOSWALL, ROBERT OLIPHANT AND CHARLES EDWARD LARARD: Aerial propellers and some test results, 303
- Cellulose (Schwalbe), 371
 Chemical industry, Problems in (Baker), 451
 COBLENTZ, W. W.: Reflecting powers of various metals, 169
 Copper, Resistance of, Temperature coefficient of (Dellinger), 213
 CRISFIELD, J. A. P.: Mechanical engineering problems in illuminating gas works, 349
 CURRENT TOPICS, 45, 77, 154, 156, 157, 193, 212, 223, 229, 268, 289, 290, 302, 316, 318, 322, 324, 344, 347, 348, 360, 369, 370, 397, 399, 418, 435, 436, 494, 495
- Deflocculation, Phenomena of (Free), 46
 DELLINGER, J. H.: Temperature coefficient of resistance of copper, 213
 Di-electric constant, Comparison of the different methods of measuring the (Floquet), 385
 DOLLECZEK, ANTON: Fuze-powder, 269
 Dynamometer, Gasolene - engine (Hopkins), 58
- Electric lighting, Vacuum - tube lighting (Moore), 361
 Explosives (Gunsolus), 124
- Flocculation, Phenomena of (Free), 46
 FLOQUET, PAUL: Comparison of the different methods of measuring the di-electric constant, 385
 Formulas, dimensional, Physical quantities classified in the order of their (Hering), 194
 FRANKLIN INSTITUTE: Charter and by-laws, 132

- Committee on science and the arts: Abstract of proceedings of the stated meeting, June 1, 1910, 67; Sept. 7, 1910, 319; Oct. 5, 1910, 389; Nov. 2, 1910, 496
- Committee on Science and the Arts, Regulations, 142
- Library notes, 71, 152, 225, 321, 392, 501
- Membership notes, 70, 151, 320, 391, 500
- Sections, Proceedings of meetings, 68, 154, 390, 498
- Proceedings of the stated meeting, June 15, 1910, 67; Sept. 21, 1910, 319; Oct. 19, 1910, 389; Nov. 16, 1910, 496
- FREE, E. E.: Phenomena of flocculation and deflocculation, 46
- Fuze-powder (Dolleczeck), 269
- Galvanometer, flat-coil, new type of (Northrup), 245
- Galvanometers, Comparison (Northrup), 245
- GARDNER, HENRY A.: The effect of crystalline pigments on the protection of wood, 117
- GARDNER, HENRY A.: The permeability of paint films, 345
- Gasolene-engine dynamometer and speedometer (Hopkins), 58
- Gas works, illuminating, Mechanical engineering problems in (Crisfield), 349
- GUNSOLUS, F. H.: Explosives, 124
- HEPBURN, JOSEPH SAMUEL: Atomic weights—an historical sketch, 217
- HEPBURN, JOSEPH SAMUEL: Recent progress in the chemistry of the sugars, 85
- HERING, CARL: Physical quantities classified in the order of their dimensional formulas, 194
- HOPKINS, N. MONROE: Hopkins Gasolene - engine dynamometer and speedometer, 58
- HYDE, EDWARD P.: Physical Production of light, 26
- Hysteresis, magnetic (Lloyd), 1
- Integrity of tests of metals (Outerbridge), 206
- JACOBUS, D. S.: The generation of power, 409
- JAYNE, HARRY WALKER: Obituary notice, 65
- JONES, WASHINGTON: Obituary notice, 224
- LARARD, CHARLES EDWARD, AND ROBERT OLIPHANT BOSWALL: Aerial propellers and some test results, 303
- Light, Physical production of (Hyde), 26
- LLOYD, MORTON G.: Magnetic hysteresis, 1
- Magnetic hysteresis (Lloyd), 1
- Mechanical engineering problems in illuminating gas works (Crisfield), 349
- Metals, Reflecting powers of (Coblentz), 169
- Metals, Tests of Integrity of (Outerbridge), 206
- MOORE, D. MCFARLAN: Vacuum-tube lighting, 361
- NORTHROP, EDWIN F.: Comparison of galvanometers and a new type of flat-coil galvanometer, 245
- OBITUARY NOTICES:
Harry Walker Jayne, 65
Washington Jones, 224
- OUTERBRIDGE, ALEXANDER, E., JR.: Integrity of tests of metals, 206
- Paint films, Permeability of (Gardner), 345
- PETIT, HENRI: Aviation and aeroplane motors, 291
- Phenomena of flocculation and deflocculation (Free), 46
- Physical production of light (Hyde), 26
- Physical quantities classified in the order of their dimensional formulas (Hering), 194
- Pigments, crystalline, Effects of, on the protection of wood (Gardner), 117
- Powder, fuze- (Dolleczeck), 269
- Power, Generation of (Jacobus), 409
- Publications received, 72, 155, 226, 398, 503
- Reflecting powers of various metals (Coblentz), 169
- Safes, fire- and burglar-proof, Recent advances in the construction of (Watson), 419

- SCHWALBE, CARL G.: Cellulose, 371
- SOUTHER, HENRY: Selection and treatment of alloy steels for automobiles, 437
- Speedometer, Gasolene-engine dynamometer and (Hopkins), 58
- Steels, alloy, Selection and treatment of, for automobiles (Souther), 437
- Storage battery engineering, Some recent problems in (Appleton), 327
- Sugars, Recent progress in the chemistry of the (Hepburn), 85
- Temperature coefficient of resistance of copper (Dellinger), 213
- TURNER, WALTER V.: The air-brake as related to progress in locomotion, 461
- Vacuum-tube lighting (Moore), 361
- WATSON, E. E.: Recent advances in the construction of fire- and burglar-proof safes, 419
- WILLIAMS, WILLIAM J.: American patents in England, 317
- Wood, Effect of crystalline pigments on the protection of (Gardner), 117



T

1

F8

v. 170

Franklin Institute,
Philadelphia
Journal

~~Physical &~~

~~Applied Sci.~~

~~Serials~~

Engineering

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY

ENGIN STORAGE

